Deliverable 5.6:

Risk Management Roadmaps for all case studies (with different degrees of detail depending on available data and analysis) including best practices

Work Package 5

This project has received funding from the European Union´s Seventh Framework Programme for Research, Technological Development and Demonstration under Grant Agreement N° 603663 for the research project PEARL (Preparing for Extreme And Rare events in coastal regions).

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Document Information

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Abstract (for dissemination, 100 words)	This document presents the development of specific and actionable roadmaps of each EU case study aiming to support flood risk management. The current report is a major unifying action for the PEARL project which incorporates, with different degree, stakeholders' perception and preferences obtained through the Learning and Action Alliances (LAAs), while promotes the use of PEARL products towards the implementation of flood resilience strategies. The roadmaps, i.e. the suggested action plan of each case, have been formed based on the 4year PEARL research and from input/suggestions by the local stakeholders reflecting the future and the actions that should be implemented in order to increase resilience of the pilot cases.
Keywords	Roadmap, case studies, action plan, future activities, measures, stakeholders

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Disclaimer

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Summary

The present report “Risk Management Roadmaps for all case studies (with different degrees of detail depending on available data and analysis) including best practices” (D 5.6) has been produced as a deliverable of Work Package 5 on the decision support and policy development for strengthening resilience of coastal regions. The abovementioned report supplements and completes the case study work documented in Deliverable 6.2 “Summary report on EU and international case studies” and Deliverable 6.3 “Synthesis report evaluating the outcomes in all case studies and cross linking of findings between them”.

In more detail, this document presents the development of specific and actionable roadmaps of each EU case study aiming to support flood risk management. The current report is a major unifying action for the PEARL project which incorporates, with different degree, stakeholders’ perception and preferences obtained through the Learning and Action Alliances (LAAs), while promotes the use of PEARL products towards the implementation of flood resilience strategies. The roadmaps, i.e. the suggested action plan of each case, have been formed based on the 4year PEARL research and from input/suggestions by the local stakeholders reflecting the future and the actions that should be implemented in order to increase resilience of the pilot cases.

The report encompasses a description of the PEARL initiative by introducing aspects of flood risk and flood risk management and briefing the developed PEARL methodologies and tools. Then it provides a concise description of the case studies on the aspects: (a) Problem description, issues & challenges, (b) PEARL outcomes highlighting what needs to be done towards a more flood resilient city and (c) the role of the LAAs, stakeholder’s and citizen’s participation. The last but most important section in the current report is the description of the roadmap itself where the engaged parties on implementing resilience measures have been listed and the suggested actions as well. Each described action is the outcome of PEARL research and stakeholders’ input which has been suggested to tackle city’s existing flood problems and seeks increase of flood resilience at the examined coastal urban systems.

Since developing roadmaps for each case study is the last task and a major unifying action of research activities, this document has been developed to concisely inform the research community but most importantly the local community of case studies about the PEARL work where actions need to be implemented towards resilience planning and management. To support this task even more, the content of this report is bilingual, i.e. English and local case study language in order to be used for dissemination purposes and rising awareness by the LAA members and/or local authorities.

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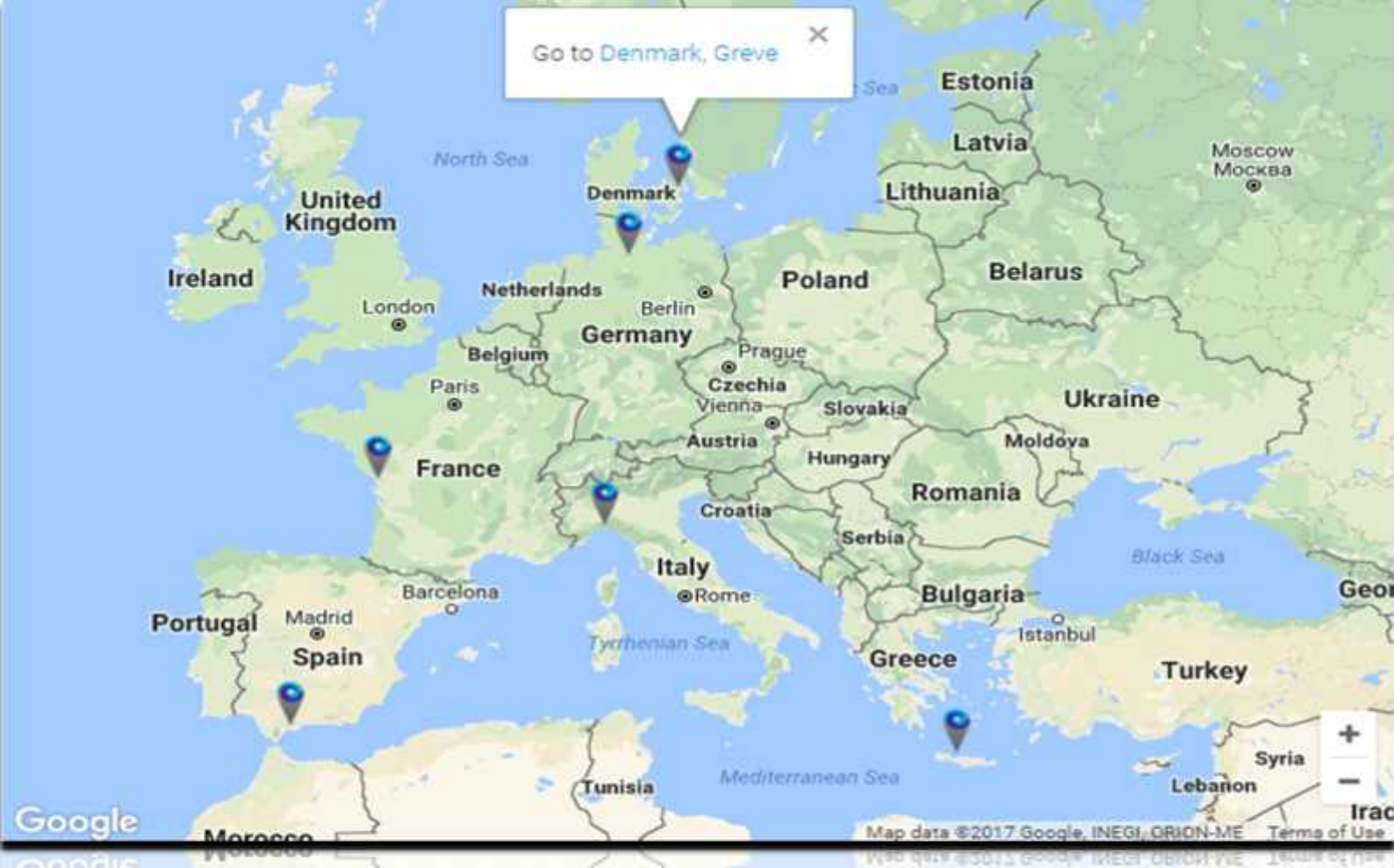
References

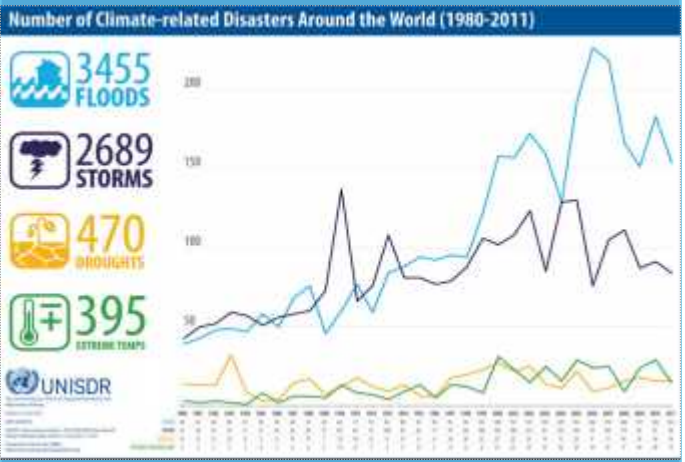


Risk Management Roadmap for the case study of Greve, Denmark

Danish Hydraulic Institute

FLOOD RISK & FLOOD RISK MANAGEMENT

Flooding & Impact/ Oversvømmelser & skader



Statistics / Statistik

Flood Types / Typer af oversvømmelser

Coastal floods are regarded as one of the most dangerous and harmful of all natural disasters. Rapid urbanisation in coastal areas combined with climate change and poor governance can lead to a significant increase in the risk of local pluvial flooding coinciding with high water levels in rivers and high tide or storm surges from the sea, posing a greater risk of devastation in coastal communities.

There is a need to improve forecasting, prediction and early warning capabilities using state of art science and technology to help policy makers and emergency services to develop robust risk reduction strategies. However, forecasting and prediction is only part of the answer. Of equal importance is the ability to effectively warn the population in areas that will be affected, and that warning systems for the general public are integrated into broader management strategies and supported by appropriate institutional and organisational arrangements. Preparing for effective response to extreme events not only involves technology but also significantly social, economic, organisational and political considerations.

Flood risk management aims to reduce the likelihood and/or the impact of floods. Experience has shown that the most effective approach is through the development of flood risk management programmes incorporating the elements of prevention, protections, preparedness, emergency response, recovery and lessons learned. Reducing human casualties and damage to economic activity and the environment are key objectives shared by all EU countries and implementation of the 2007 Floods Directive has an important role in making this happen.

The Directive applies to all kinds of floods (river, lakes, flash floods, urban floods, coastal floods, including storm surges and tsunamis) and it is being implemented in a three-base process i.e. the preliminary flood risk assessment, the development of floods hazard and flood risk maps and eventually the production of flood risk management plans. River Basin Districts are the main units for the management of river basins, as described within the Water Framework Directive, therefore, they were adopted for the EU Flood Directive too.

Flood maps are being used by many different stakeholders within flood risk management and serve purposes related to prevention of the build-up of new risk, reduction of existing ones and adaptation to changing risk factors. Development and use of flood maps serves multiple purposes such as conduction of flood risk management plans, land use planning and land management, emergency planning, public awareness raising and within the private sector e.g. insurance assessment and pricing.

Floods, among others, are commonly referred to as natural disasters but they are not in fact the results of nature-related processes alone. They are to an ever-increasing extent directly attributable to various social, economic, historical, political and even cultural issues. The perception of flood impact on life and daily activities can be significantly different amongst the population and the level of knowledge and understanding of flood risk in a given area is directly related to people's decisions to either adjust their living to such a risk or simply to ignore it.

The PEARL project sought to fill in the lack of interaction between social aspects and technical measures – appearing to be a major hindrance for solving some of the greatest problems associated with floods and flood-related disasters.

RISIKO FRA OVERSVØMMELSE OG OVERSVØMMELSESRISIKOSTYRING

Kystnære oversvømmelser betragtes som en af de mest farlige skadelige af alle naturkatastrofer. Hurtig urbanisering i kystområd kombineret med klimaændringer og dårlig governance kan føre til betydelig stigning i risikoen for lokale oversvømmelse fra ekstremreg der falder sammen med høje vandniveauer i åer og højvande el stormflod fra havet, som tilsammen udgør en større risiko ødelæggelse i kystnære områder.

Der er behov for at forbedre prognoser, forudsigelser og tidli advarsler ved hjælp af state of the art videnskab og teknologi for hjælpe beslutningstagere og bedredskabet til at udvikle robus risikoreducerende strategier. Forudsigelse og varsling er dog kun del af svaret. Af lige stor betydning er evnen til effektivt at adva befolkningen i områder, der vil blive påvirket, og at advarselssystem for offentligheden integreres i bredere ledelsesstrategier understøttes af passende institutionelle og organisatoriske redskab Forberedelse til effektive reaktioner på ekstreme begivenhed involverer ikke kun teknologi, men også væsentligt socia økonomiske, organisatoriske og politiske overvejelser.

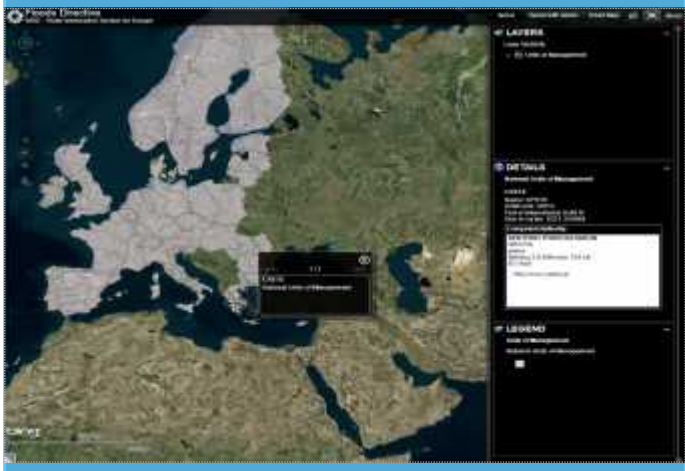
Risikostyring af oversvømmelser har til formål at reduce sandsynligheden og / eller virkningen af oversvømmelser. Erfaring har vist, at den mest effektive tilgang er gennem udvikling oversvømmelsesrisikostyringsprogrammer, der omfatter elementer forebyggelse, beskyttelse, varsling, beredskab, genopretning erfaringer. Reduktion af menneskelige tab og skade på økonomi aktivitet og miljø er de centrale mål, der er fælles for alle EU-lande, gennemførelsen af 2007-oversvømmelsesdirektivet spiller en vig rolle for at få det til at ske.

Direktivet finder anvendelse på alle former for oversvømmelser flod, søer, bymæssige kanaler, kystnære oversvømmelser, herund stormflod og tsunamier), og det gennemføres i en trefaset proces, dv den foreløbige oversvømmelsesrisikovurdering, udvikling oversvømmelser risiko- og oversvømmelsesrisikokort og i sidste en produktionen af oversvømmelsesrisikostyringsplaner. Vandoplande de vigtigste enheder til forvaltning af vandløbsområder, som beskrev i vandrammedirektivet, og de blev derfor også vedtaget for EU oversvømmelsesdirektiv.

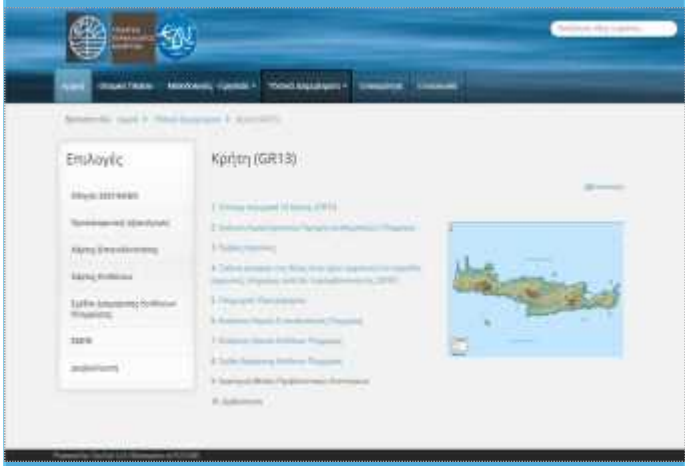
Oversvømmelseskort bruges af mange forskellige interessenter ind for oversvømmelsesrisikostyring og tjener formål med forebyggelse opbygning af ny risiko, reduktion af eksisterende og tilpasning skiftende risikofaktorer. Udvikling og brug af oversvømmelsesk tjener flere formål så som: udvikling af oversvømmelse risikostyringsplaner, arealanvendelsesplanlægning og arealforvaltnin beredskabsplanlægning, bevidstgørelse af offentligheden og inden den private sektor, f.eks. forsikringsvurdering og prisfastsættelse.

Oversvømmelser, blandt andet, omtales ofte som naturkatastrof men de er ikke i virkeligheden alene resultaterne af naturrelatere processer. De er i stigende grad direkte henført til forskellige socia økonomiske, historiske, politiske og lige kulturelle handling Opfattelsen af oversvømmelsers påvirkninger af liv og dagli aktiviteter kan være væsentligt anderledes blandt befolkningen, niveauet for viden og forståelse for oversvømmelsesrisiko i et giv område er direkte relateret til folks beslutninger om enten at tilpas deres levevis til en sådan risiko eller simpelthen at ignorere det.

PEARL-projektet søgger at udfylde manglen på interaktion mellem sociale aspekter og tekniske foranstaltninger – som synes at være en stor hindring for at løse nogle af de største problemer i forbindelse med oversvømmelser og oversvømmelsesrelaterede katastrofer.



Flood Directive / Oversvømmelsesdirektivet



Implementation / Implementering

Management / Management

THE PEARL PROJECT: Methods & Tools

PEARL Project / PEARL Projektet

Case Studies / Case Studier

Partners / Partnere

The PEARL project, a collaborative research project with 4year duration, worked towards the development of adaptive, sociotechnical risk management measures and strategies for coastal communities against extreme hydro-meteorological events minimising social, economic and environmental impacts and increasing the resilience of Coastal Regions in Europe. PEARL received funding from the European Union's Seventh Framework Programme for Research, Technological Development and Demonstration (EU-FP7) under the theme "Coasts at threat in Europe: tsunamis and climate-related risks" (ENV.2013.6.4-3).

The PEARL consortium consisted of 24 partners from 13 countries from Europe and Asia, with significant experiences of severe flood risk in coastal regions and advanced flood early warning systems. Project's leader was the UNESCO-IHE.

The project examined 6 case studies from across Europe and 5 pilots from the Caribbean and Asia. Those were:

- Greve, Denmark
- Elbe Estuary, Germany
- Les Boucholeurs, France
- Genoa, Italy
- Marbella, Spain
- Rethymno, Crete, Greece
- St. Maarten
- St. Lucia
- Tohoku, Japan
- Taiwan
- Ayutthaya, Thailand

The research activities which were conducted within the project provided a plethora of products i.e. methodological frameworks, tools and applications, as well as policy briefs and publications. The most indicative ones were:

- Risk and Root Cause Assessment framework
- Vulnerability assessment framework
- Innovative hazard assessment and modelling concepts for individual or combined extreme events and several scales
- Frameworks for impact/damages (direct/indirect, tangible/intangible), economic and public health impact assessment due to multiple causes and scenarios
- Toolkit for holistic/multiple risk and impact/damage assessment at strategic and operational levels
- Operational Early Warning Systems and new methodologies for their effective dissemination
- Novel methodologies and concepts for achieving faster simulations and for uncertainty propagation analysis
- Frameworks for stakeholders' analysis and engagement i.e. the Learning and Action Alliances
- Frameworks and tools for flood resilience assessment of urban systems
- Intelligent knowledge base for resilience measures and strategies and tools/algorithms supporting their selection
- Interactive web-based learning and planning platform
- Risk Management Roadmaps specifically tailored to case study needs
- Information system infrastructure for data and meta data management

All outcomes/products and their integration formed the holistic approach and eventually the PEARL holistic framework enhancing prevention, mitigation and preparedness capabilities and building flood resilience of coastal urban systems.

PEARL INIATIVET

http://www.pearl-fp7.eu/

PEARL-projektet, et samarbejdsprojekt med 4 års varighed, har arbejdet med udvikling af adaptive, sociotekniske risikostyringsforanstaltninger og strategier for kystsamfund mod ekstreme meteorologiske hændelser, der minimerer sociale, økonomiske og miljømæssige konsekvenser og øger modstandsdygtigheden i kystområderne i Europa . PEARL modtog finansiering fra EU's syvende rammeprogram for forskning, teknologisk udvikling og demonstration (EU-FP7) under temaet "Kyststrande i trussel i Europa: tsunamier og klimarelaterede risici" (ENV.2013.6.4-3).

PEARL-konsortiet bestod af 24 partnere fra 13 lande fra Europa og Asien med betydelige erfaringer med alvorlig oversvømmelsesrisiko i kystområder og avancerede systemer til tidlig varsling af oversvømmelser. Projektets leder var UNESCO-IHE.
Projektet undersøgte 6 casestudier fra hele Europa og 5 piloter fra Caribien og Asien. Det var:

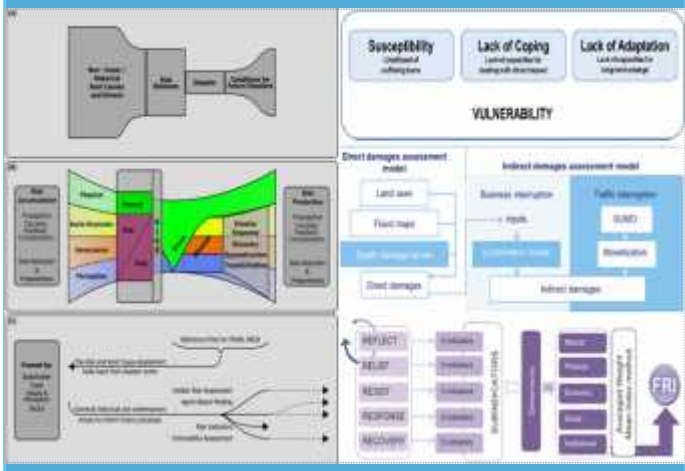
- Greve, Danmark
- Elbe Estuary, Tyskland
- Les Boucholeurs, Frankrig
- Genova, Italien
- Marbella, Spanien
- Rethymno, Kreta, Grækenland
- St. Maarten
- St. Lucia
- Tohoku, Japan
- Taiwan
- Ayutthaya, Thailand

Forskningsaktiviteterne, som blev gennemført inden for projektet, gav et væld af produkter, dvs. metodiske rammer, værktøjer og applikationer samt politiske briefs og publikationer. De mest vejledende var:

- Risiko- og årsagssammenhængsramme
- Sårbarhedsvurderingsramme
- Innovative risikovurdering og modelleringskoncepter til individuelle eller kombinerede ekstreme begivenheder og flere skalaer
- Rammer for indvirkning / skader (direkte / indirekte, materielle / immaterielle), konsekvensanalyse af økonomiske og folkesundheden på grund af flere årsager og scenarier
- Værktøjskasse til holistisk / multipel risiko og konsekvens / skade vurdering på strategiske og operationelle niveauer
- Operative Early Warning Systems og nye metoder til effektiv formidling
- Nye metoder og koncepter til opnåelse af hurtigere simuleringer og usikkerhedsudbredelsesanalyse
- Rammer for interessenters analyse og engagement, dvs. lærings- og handlingsallianserne
- Rammer og værktøjer til vurdering af oversvømmelsesmodstandsdygtighed i bysystemer
- Intelligent vidensbase for modstandsdygtighed og strategier og værktøjer / algoritmer, der understøtter deres valg
- Interaktiv web-baseret lærings- og planlægningsplatform
- Risk Management Roadmaps specielt skræddersyet til case study behov
- Informationssysteminfrastruktur til data- og metadatahåndtering

Alle resultater / produkter og deres integration dannede den holistiske tilgang og i sidste ende den hollandske PEARL-ramme, der forbedrede forebyggelse, begrænsning og beredskabskapacitet og opbygning af oversvømmelsesfasthed i kystbysystemer.

PEARL PROJEKTET: Metoder og Værktøj

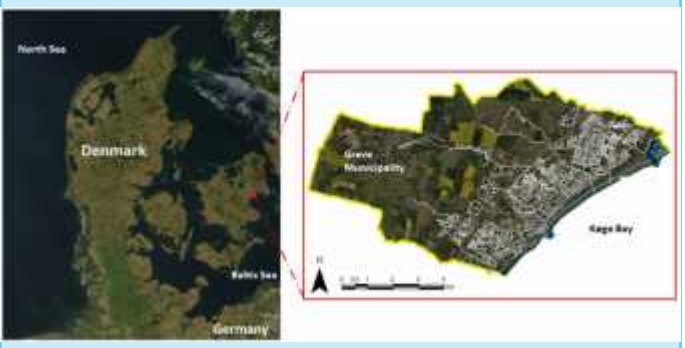


Methodologies / METODER

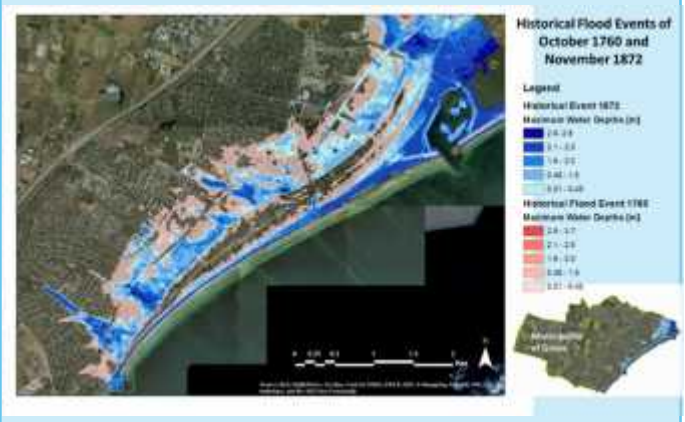
Tools & Application / Værktøj og Anvendelser

Publications & Policy Briefs / Publikationer

PROBLEM DESCRIPTION, ISSUES & CHALLENGES



Location of the Greve Case Study Area in eastern Denmark/ Greve i Øst Danmark.



Plots of historical flood events in Greve in October 1760 with an estimated maximum water level of 3.7 m and November 1872 with an estimated water level of 2.8 m estimated using Terrain Analysis/ Historiske oversvømmelseskort i Greve for oktober 1760 med vandniveau på 3,7 m og november 1872 med vandniveau på 2,8 m ved terrænanalyse (Berbel Roman, 2014).

The coastal area of Greve Municipality in Eastern Denmark is a case study area in the PEARL project. Greve municipality is a sub-urban area located 20 km southwest of the Danish capital, Copenhagen. The municipality is around 60 km^2 in size, with 9 km of coast to the southeast bordering the Baltic Sea at Køge Bay.

The coast of Greve is the focus area in the case studies in the PEARL project. It is the most densely built-up area in the municipality characterized by relatively flat and low-lying terrain with elevations of just between 2-6 m MSL. The coastal area along Køge Bay, with its sandy beaches and natural ecosystems, is highly attractive to local and tourist populations alike, leading to the development of numerous holiday homes and residential houses in the area. In addition, Greve is part of an industrial area in the south of Copenhagen. However, Greve is considered one of the most flood-prone areas in Denmark (EC, 2009). It is under threat of flooding from multiple hazards such as:

- Extreme rainfall
- Storm surges

The area had been seriously affected by flooding in the past—recently in 2002, and again in 2007 from extreme rainfall (Greve Kommune, 2007; Sto. Domingo et al., 2010), and the region is also at risk from coastal flooding from storm surges and general sea level rise because of its coastal location (Vestergaard, 2011). In July 2007, a series of rain events with an estimated return period of 500 years caused severe flooding in Greve (Greve Kommune, 2007).

In addition to extreme rainfall, Greve is also vulnerable to flooding from extreme sea levels along its coast. Greve is at risk from coastal flooding due to storm surges and general water level increase because of its location in Køge Bay (Vestergaard, 2011), which has been identified as 1 of 10 most at-risk areas in Denmark from coastal flooding (NIRAS, 2014).

There have been 28 documented high sea level events in Køge Bay with magnitudes greater than 1.52 m—the highest water level observed in the area in 1955-2002. The highest sea level ever recorded in Køge Bay was in October 1760 reaching an estimated 3.7 m. In addition, in November 1872, sea levels reached 2.8 m causing widespread flooding in the area (Madsen, 2008; Colding, 1881).

In the PEARL project, Greve was used as a case study area in developing a holistic risk reduction framework against extreme events in coastal regions. It figured in work on understanding the formation of hazards under extreme events as a test and application area to develop a set of extreme event scenarios, and test the tools developed for estimation of hazards under extreme events. Also, Greve was used as a case area to improve the speed of state-of-the-art modelling tools for early warning, develop methods for fast flood simulations in areas with combined flood risks, and evaluate methods for uncertainty propagation and its impacts on early warnings and real-time decision-making.

CASE STUDY OVERSIGT

PROBLEMBESKRIVELSE UDFORDRINGER

Kystområdet Greve Kommune i Østdanmark er et case study-område i PEARL-projektet. Greve kommune er et underbyområde, der ligger 20 km sydvest for den danske hovedstad, København. Kommunen er omkring 60 km2 i størrelse med 9 km kyst mod sydøst ved Østersøen ved Køge Bugt.

Greves kyst er fokusområdet i casestudierne i PEARL-projektet. Det er det mest tætte bebyggede område i kommunen præget af relativt fladt og lavtliggende terræn med forhøjelser på lige mellem 2-6 m MSL. Kystområdet langs Køge Bugt, med sine sandstrande og naturlige økosystemer, er yderst attraktivt for både lokale og turistbefolkninger, hvilket fører til udvikling af mange ferieboliger og boliger i området. Herudover er Greve en del af et industriområde i det sydlige København. Greve betragtes dog som et af de mest oversvømmede områder i Danmark (EF, 2009). Det er truet af oversvømmelser fra flere farer som:

- Ekstreme nedbør
- Stormflow

Området blev alvorligt ramt af oversvømmelse i det seneste for nylig i 2002, og igen i 2007 fra ekstrem nedbør (Greve Kommune, 2007, Sto. Domingo et al., 2010), og regionen er også i fare for kystnære oversvømmelser fra stormstigninger og generel havniveau stige på grund af sin kystnære beliggenhed (Vestergaard, 2011). I juli 2007 forårsagede en række regnhændelser med en estimeret returperiode på 500 år svær oversvømmelse i Greve (Greve Kommune, 2007).

Ud over ekstreme nedbør er Greve også sårbar over for oversvømmelser fra ekstreme havniveauer langs kysten. Greve er i fare for kystnære oversvømmelser på grund af stormstød og generel vandstandsforøgelse på grund af beliggenheden i Køge Bugt (Vestergaard, 2011), der er blevet udpeget som 1 ud af 10 mest risikoområder i Danmark fra kystnære oversvømmelser (NIRAS, 2014).

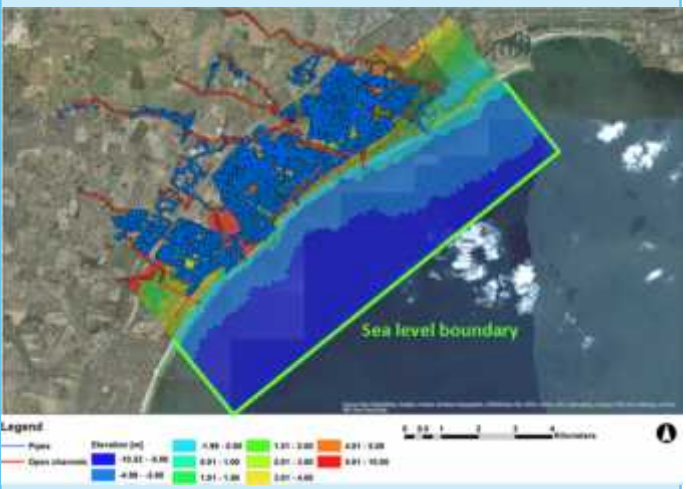
Der har været 28 dokumenterede høje havniveauer i Køge Bugt med størrelser større end 1,52 m-det højeste vandniveau, der blev observeret i området i 1955-2002. Det højeste havniveau, der nogensinde blev registreret i Køge Bugt, nåede i oktober 1760 en skønsmæssig 3,7 m. Desuden nåede søfladerne i november 1872 2,8 m og forårsagede udbredt oversvømmelse i området (Madsen, 2008; Colding, 1881).

I PEARL-projektet blev Greve brugt som et case study-område med at udvikle en holistisk risikoreducerende ramme mod ekstreme begivenheder i kystområder. Det var i arbejdet med at forstå dannelsen af farer under ekstreme begivenheder som et test- og applikationsområde for at udvikle et sæt ekstreme begivenhedsscenarier, og test de værktøjer, der er udviklet til vurdering af farer under ekstreme begivenheder. Greve blev også brugt som et sagsområde for at forbedre hastigheden på state-of-the-art modelleringsværktøjer til tidlig varsling, udvikle metoder til hurtige oversvømmelsessimuleringer i områder med kombineret oversvømmelsesrisiko og vurdere metoder til udbredelse af usikkerhed og dens indvirkning på tidlige advarsler og beslutningstagning i realtid.

The case study area (red dotted line) within Greve Municipality/ Case studieområdet (rød prikket linje) i Greve Kommune.

PEARL OUTCOMES

highlighting what needs to be done towards a more flood resilient city



A plot of the 1D-2D coastal flood model for Greve. A 1D model of the drainage system comprising of streams (red lines) and stormwater sewers (blue lines and points) is linked to a 2D mesh model of the coast (coloured areas)/ 1D-2D oversvømmelsesmodel for Greve.

The PEARL project aimed at developing a holistic risk reduction framework against extreme events in coastal regions. The project analysed the formation of hazards under extreme events, and Greve was used as a case area for testing the framework, concepts, and tools for estimation of hazards under extreme events developed under the project.

New methods to simulate extreme event drivers/phenomena, and modelling of individual and concurrent coastal flood hazards under extreme event conditions were performed. A new coupled global (GCM) and regional (RCM) climate model was developed and used to investigate regional sea level rise and changes in extreme sea level event statistics in European coasts, including Køge Bay in Greve. The outputs of the climate model were subsequently used to drive high-resolution models to analyse changes in extreme storm events. A high-resolution atmospheric model was also developed for investigating extreme precipitation events in the case study areas, including Greve (PEARL, 2016).

A method for generating storm surge hydrographs based on statistical analysis was also developed in the project. The method was implemented in a storm surge simulator to generate storm surge hydrographs of various return periods for an area. In addition, an integrated hazard-modelling framework focusing on wave modelling was developed for Køge Bay in Greve (PEARL, 2016).

Finally, flood hazard modelling considering extreme rainfall and sea surge events, occurring individually and concurrently, was performed in the Greve case study using coupled 1D/2D flood modelling, as well as integrated 2D/3D adaptive mesh modelling (PEARL, 2017c). The study analysed flood risks not only from single-forcing flood events, but also for concurrent events, and analysis results revealed the most at risk areas from flooding in Greve, such as those around the northern and southern harbours.

Greve was also used as a case area in the development of tools and techniques for flood forecasting and early warning systems in coastal regions. An online real-time coastal flood forecasting system for the area was developed and implemented. More details on these techniques are found in Deliverable D4.1 “Report on novel online modelling tools and techniques for early warning systems” (PEARL, 2016).

An online site was built for the case area, where flood map and flood level forecasts are routinely computed and published. The operational system employs a hydrodynamic flood model using forecasted rainfall and sea water levels.

Greve was also used as a test case in developing techniques for faster model simulations. The flood forecast model was optimised to achieve fast and accurate flood simulations appropriate for real-time forecasting. The following model speed-up techniques were tested and evaluated in the case study:

- Modification of computational grid type
- Optimisation of computational grid size
- Parallelisation of computations
- Use of Graphics Processing Unit (GPU) computing

These techniques are described in detail in Deliverable D4.2 “Guidelines on achieving faster simulations for early warning” (PEARL, 2017a). The report presents further analysis and description on models and applied methodologies along with discussion on results.

CASE STUDY OVERSIGT

http://www.pearl-fp7.eu/

PEARL-projektet havde til formål at udvikle en holistisk risikoreducerende ramme mod ekstreme begivenheder i kystområder. Projektet analyserede dannelsen af farer under ekstreme begivenheder, og Greve blev brugt som et sagsområde for at teste rammerne, koncepter og værktøjer til vurdering af farer under ekstreme begivenheder udviklet under projektet.

Nye metoder til simulering af ekstreme begivenhedsdrivere / fænomener og modellering af individuelle og samtidige kystnære oversvømmelsesfarer under ekstreme hændelsesforhold blev udført. En ny koblet global (GCM) og regional (RCM) klimamodel blev udviklet og anvendt til at undersøge den regionale stigning i havniveauet og ændringer i ekstreme havniveauhændelsesstatistikker i europæiske kyster, herunder Køge Bugt i Greve. Udgangene fra klimamodellen blev senere brugt til at køre højopløsningsmodeller til analyse af ændringer i ekstreme stormhændelser. En atmosfærisk model med høj opløsning blev også udviklet til undersøgelse af ekstreme nedbørshændelser i case-studieområderne, herunder Greve (PEARL, 2016).

En metode til generering af storm surge hydrografer baseret på statistisk analyse blev også udviklet i projektet. Metoden blev implementeret i en storm surge simulator for at generere storm surge hydrografer af forskellige returperioder for et område. Derudover blev der udviklet en integreret risikomodelleringsramme med fokus på bølgemodellering for Køge Bugt i Greve (PEARL, 2016).

Endelig blev flodfaremodellering i betragtning af ekstreme nedbør og havbølgehændelser, der fandt sted individuelt og samtidigt, udført i Greve-casestudiet ved hjælp af koblet 1D / 2D-flodmodellering samt integreret 2D / 3D adaptiv meshmodellering (PEARL, 2017c). Undersøgelsen analyserede oversvømmelsen risikerer ikke kun fra enkeltkrævende oversvømmelseshændelser, men også for samtidige hændelser, og analyseresultater afslørede mest på risikoområder fra oversvømmelser i Greve, såsom dem omkring de nordlige og sydlige havne.

Greve blev også brugt som et sagsområde i udviklingen af værktøjer og teknikker til oversvømmelsesprognoser og tidlig varslingssystemer i kystområder. Et online real-time kystoversvømmelsesprognosesystem for området blev udviklet og implementeret. Flere detaljer om disse teknikker findes i Deliverable D4.1 "Rapport om nye online modelleringsværktøjer og teknikker til tidlig varslingssystemer" (PEARL, 2016).

Et websted blev bygget til case-området, hvor oversigtsoversigt og overslag over flodniveau beregnes rutinemæssigt og offentliggøres. Operativsystemet anvender en hydrodynamisk oversvømmelsesmodel ved hjælp af prognosticerede nedbør og havvandsniveauer.

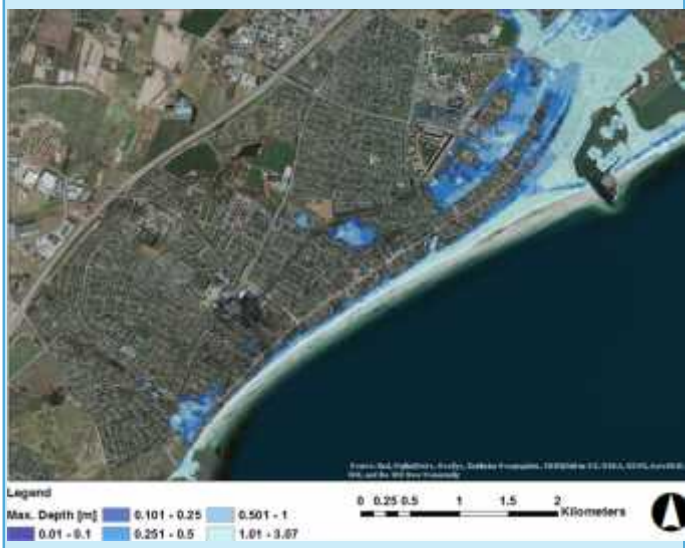
Greve blev også brugt som et test tilfælde i udviklingsteknikker til hurtigere modelsimuleringer. Oversvømmelsesprognosemodellen blev optimeret for at opnå hurtige og præcise oversvømmelsessimuleringer, der passer til real-time prognoser. Følgende modelhastighedsteknikker blev testet og evalueret i casestudiet:

- Modifikation af beregningsnettetype
- Optimering af beregningsnettet størrelse
- Parallelisering af beregninger
- Brug af grafikbehandlingsenhed (GPU) computing

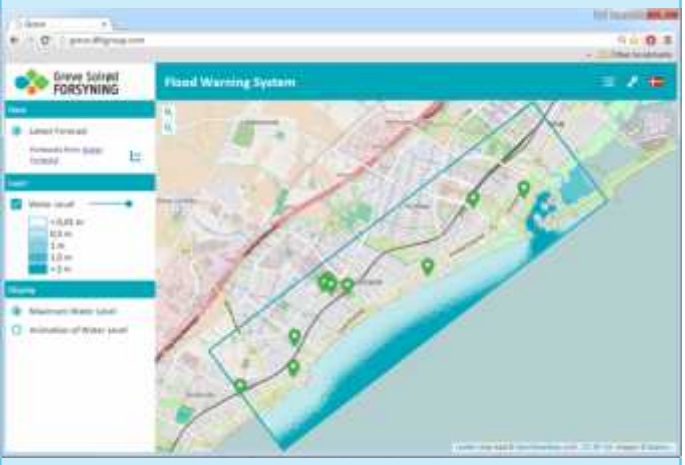
Disse teknikker er beskrevet detaljeret i Leverbar D4.2 "Retningslinjer for opnåelse af hurtigere simuleringer til tidlig varsling" (PEARL, 2017a). Rapporten præsenterer yderligere analyse og beskrivelse af modeller og anvendte metoder sammen med diskussion om resultater.

PEARL RESULTATER

Fokus på hvad der skal til for at gøre byer mere resilliente



THE ROLE OF LAAs, STAKEHOLDERS' & CITIZENS' PARTICIPATION



Homepage for the online coastal flood warning system in Greve, Denmark/ Hjemmeside for det online forecast system i Greve (www.greve.dhigroup.com) (Source: PEARL, 2016).

Local stakeholder involvement in the Greve Case Study was limited to coordination with the local utility company regarding data about the area.

The municipal office and local utility company operating the collection system provided great support in terms of data and information provision and expressed high interest in the case study. However, they also actively and continuously conduct their own analyses for improving their system. For example, stemming from past flood events in 2002 and 2007, it was politically decided that the drainage system should be upgraded to handle a maximum flooding frequency of only once every 10 years. A vulnerability map was prepared for the city using GIS, and climate adaptation plans for implementation over the next 12-15 years were developed (EC, 2009; Kelder, 2011). Nevertheless, they make good use of the real-time flood forecast system established under the PEARL project for storm surge warning.

The city has taken advantage of hydraulic modelling tools and measurement campaigns for detailed evaluation of prioritisation areas in their climate adaptation plans. In August 2010, when several locations in Denmark were affected by very heavy rainfall and severe flooding, Greve avoided major flood damages. Knowledge and learning from past events allowed the Municipality and local utility company to manage and handle this extreme event and avoid major flooding (Kelder, 2011).

Lokal interessentinddragelse i Greve-casestudiet var begrænset til koordinering med det lokale forsyningsfirma vedrørende data om området.

Kommunalbureauet og det lokale forsyningsselskab, der opererer indsamlingssystemet, ydet stor støtte til data og information og udtrykte stor interesse i casestudiet. Men de gennemfører også aktivt og kontinuerligt deres egne analyser for at forbedre deres system. For eksempel som følge af tidligere oversvømmelseshændelser i 2002 og 2007, blev det politisk besluttet, at drænsystemet skulle opgraderes for at håndtere en maksimal oversvømmelsesfrekvens på kun en gang hvert 10. år. Et sårbarhedskort blev udarbejdet for byen ved hjælp af GIS, og der blev udviklet klimatilpasningsplaner for implementering i løbet af de næste 12-15 år (EF, 2009; Kelder, 2011). Ikke desto mindre gør de godt brug af det realtidsoversvømmelsesprognosesystem, der er oprettet under PEARL-projektet for storvarmevarsel.

Byen har udnyttet hydrauliske modelleringsværktøjer og målekampagner til detaljeret evaluering af prioriteringsområder i deres klimatilpasningsplaner. I august 2010 undgik Greve store oversvømmelsesskader, da flere steder i Danmark var ramt af meget kraftig nedbør og svær oversvømmelse. Viden og læring fra tidligere begivenheder gav kommunen og det lokale værtsfirma mulighed for at styre og håndtere denne ekstreme begivenhed og undgå

PARTIES INVOLVED

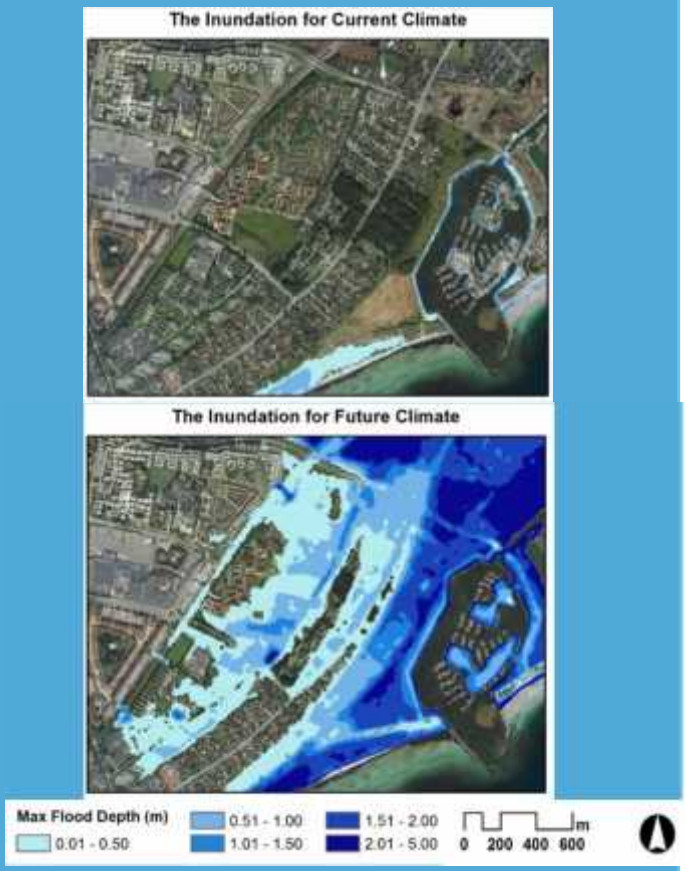
KLAR Forsyning (http://www.klarforsyning.dk/) is the local utility company operating the collection system in Greve. They, together with the municipality, supported the case study in terms of providing needed data for the project.

KLAR Forsyning is responsible for providing the various utility services in the municipality, such as waste management, wastewater treatment, water and heating, and stormwater management. Their responsibilities include the conduct of studies on future needs for climate adaptation. They plan and execute various climate adaptation projects for the municipality, also involving citizens to create creative solutions that address the issues and at the same time enhance the living environments.

KLAR Forsyning (http://www.klarforsyning.dk/) er det lokale forsyningsselskab, der driver indsamlingssystemet i Greve. De støttede sammen med kommunen casestudiet med hensyn til at levere nødvendige data til projektet.

KLAR Forsyning er ansvarlig for at levere de forskellige forsyningstjenester i kommunen, såsom affaldshåndtering, spildevandsrensning, vand og varme samt stormvandsforvaltning. Deres ansvar omfatter undersøgelsen af fremtidige behov for klimatilpasning. De planlægger og udfører forskellige klimatilpasningsprojekter for kommunen, der også involverer borgerne til at skabe kreative løsninger, der løser problemerne og samtidig forbedrer de levende miljøer.

GROUP OF ACTIVITIES: A climate adaptation plan



Comparison of estimated flooding for Current (top) and Future scenarios (down) of 100-yr storm surge events in part of the study area in Greve/ Sammenligning af estimeret oversvømmelse for Nuværende (øverste) og Fremtidige scenarier (ned) af 100-års storvandsbegivenheder i studieområdet (Source: Asyhari, 2017)

Through analysis of the formation of coastal flood hazards under extreme events in Greve, information on potential current and future climate change risks in the area for individual as well as concurrent extreme events were obtained in the case study. Besides the flood hazard maps from individual and concurrent flood scenarios produced from the study, a GIS-based flood damage and risk analysis tool was also applied, primarily as a test case for the newly-developed damage assessment tool, and also to obtain quantitative measures of flood risk in the area. CADSS (City Adaptation Decision Support System) is a new flood damage modelling tool developed in DHI supporting the decision-making process in relation to quantitative risk and damage assessment (Asyhari, 2017). The tool uses hazard maps together with data on valued assets and estimates of financial damage measures (e.g. depth-damage curves) in a study area to calculate monetary values for direct and indirect tangible flood damages and risks.

Based on estimates, climate change significantly increases flood risks in the study area, particularly for storm surge events. A comparison of flood estimates for Current and Future projections for 100-yr storm surge events is presented. Using CADSS, the impact of climate change on flood risks from extreme rainfall and storm surge events was evaluated.

Flood risk and damage estimates were used to develop and evaluate strategies for flood alleviation and protection in the case area. Though current traditional flood protection systems rely heavily on structural measures, a shift towards a more holistic approach of flood risk management is increasingly encouraged (Hartmann & Albrecht, 2014).

A climate adaptation plan based on the principle of holistic flood risk management approach was explored in the study, comprising of:

1. City planning focusing on retaining as much water as possible using available spaces in the case area, such as parks, parking spaces, and detention ponds
2. The outlets of the drainage system need automatic gates to prevent backflow from the sea into the drainage system
3. Existing dikes along the coast may be raised to anticipate projected future mean sea level rise
4. Installation of new pumping stations in low-lying areas to drain the water during flood events
5. Use of the Online Flood Forecasting System
6. Strategic use of temporary dikes (water tubes) in the area upon forecast of storm surges

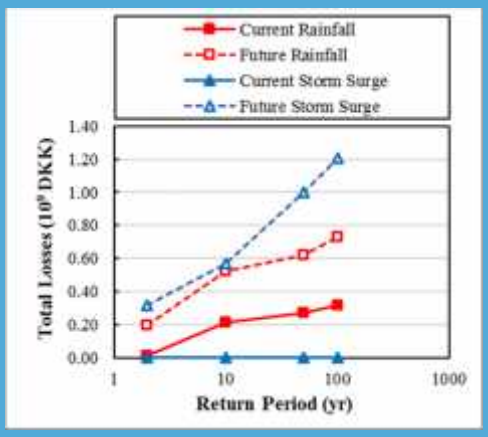
The above-mentioned options (1-4) were implemented in the coastal flood model, and flood hazards and risks were re-evaluated. The reduction in flood risks resulting from the proposed adaptation measures were estimated using CADSS. With the decrease in flood extents and magnitudes in the case area significant reductions in damages could be realised, as shown in the table for the case of concurrent event scenarios. For the most extreme event, in which a 100-yr rainfall event occurs simultaneously with 100-yr storm surge event, the flood damage decreased from 2.1 billion to 566 million DKK.

The effectiveness of the proposed options, based on the percentage of damage reduction, was high estimated at 88% for Current, and 82% for Future climate scenarios. The efficiency, based on the benefit-cost ratio, was also deemed high with ratios above 1 for both Current and Future scenarios.

Gennem analyse af oversvømmelsesrisiko under ekstreme begivenheder i Greve blev der opnået oplysninger om potentielle nuværende og fremtidige klimaændringer i området for individuelle såvel som samtidige ekstreme begivenheder i casestudiet. Foruden oversvømmelses-farekortene fra individuelle og samtidige oversvømmelses-scenarier, der blev produceret fra undersøgelsen, blev der også anvendt et GIS-baseret oversvømmelseskader og risikoanalyseværktøj, primært som et testforløb for det nyudviklede skadevurderingsværktøj og også for at opnå kvantitative foranstaltninger af oversvømmelsesrisiko i området. CADSS (City Adaptation Decision Support System) er et nyt oversvømmelsesskader modelleringsværktøj udviklet i DHI, der støtter beslutningsprocessen i relation til kvantitativ risiko og skadevurdering (Asyhari, 2017). Værktøjet anvender farekort sammen med data om værdiansatte aktiver og skøn over finansielle skadeforanstaltninger (fx dybdebeskadigelseskurver) i et studieområde for at beregne monetære værdier for direkte og indirekte håndgribelige oversvømmelsesskader og risici.
Baseret på estimater øger klimaforandringerne betydeligt oversvømmelsesrisici i undersøgelsesområdet, især for stormflodshændelser. En sammenligning af oversvømmelsesestimater for nuværende og fremtidige fremskrivninger for 100-års stormhændelser er præsenteret i øverste venstre figur. Ved hjælp af CADSS blev virkningen af klimaændringer på oversvømmelsesrisici fra ekstreme nedbør og stormflodhændelser vurderet.
Oversvømmelsesrisiko og skøn estimater blev brugt til at udvikle og evaluere strategier for oversvømmelse lindring og beskyttelse i sagen område.

En undersøgelse af klimatilpasning baseret på princippet om holistisk oversvømmelsesrisikostyringsmetode blev undersøgt i studiet omfattende:
1. Byplanlægning med fokus på at opretholde så meget vand som muligt ved hjælp af ledige rum i sageområdet, såsom parker, parkeringspladser og frihedsvagter
2. Afløbssystemets udløb har brug for automatiske porte for at forhindre tilbagestrømning fra havet i afløbssystemet
3. Eksisterende dykker langs kysten kan hæves for at forudse forventet fremtidig gennemsnitlig havstigning
4. Installation af nye pumpestationer i lavtliggende områder for at dræne vandet under oversvømmelseshændelser
5. Brug af Online Flood Forecasting System
6. Strategisk brug af midlertidige dykninger (vandrør) i området ved prognose af stormstød
Ovennævnte muligheder (1-4) blev implementeret i kystnære oversvømmelsesmodel, og oversvømmelsesrisici og risici blev reevalueret. Reduktionen i oversvømmelsesrisici som følge af de foreslåede tilpasningsforanstaltninger blev anslået ved hjælp af CADSS. Med faldet i oversvømmelser og størrelser i sagen kunne betydelige reduktioner i skader realiseres som vist i højre tabel for tilfælde af samtidige hændelsesscenarier. For den mest ekstreme begivenhed, hvor der forekommer en 100-års nedbørshændelse samtidig med en 100-års storvandsbegivenhed, faldt oversvømmelsesskaderne fra 2,1 mia. Til 566 mio. Kr.
Effektiviteten af de foreslåede muligheder, baseret på procentdelen af skadereduktion, blev højest estimeret til 88% for Current og 82% for fremtidige klimascenarier. Effektiviteten baseret på fordelings- og omkostningsforholdet blev også anset for høj med forhold over 1 for både nuværende og fremtidige scenarier.

GRUPPE AKTIVITETER: Muligheder for klimatilpasning



Quantitative estimates of financial damages from Current and Future rainfall and storm surge events in the study area evaluated using CADSS/ Økonomiske skader fra Nuværende og Fremtidige nedbør og stormflodhændelser i undersøgelsesområdet evalueret ved CADSS (Source: Asyhari, 2017)

Overview of coastal flood adaptation options in the study area/ Klimatilpasningsmuligheder i undersøgelsesområdet (Source: Asyhari, 2017)

LESSONS LEARNED, RESULTS & DISCUSSION

Comparison of flooding from 100-yr future storm surge event with (down) and without (top) flood adaptation options/ Sammenligning af oversvømmelser fra 100-års fremtidige stormflodshændelse med (ned) og uden (øverste) klimatilpasning (Source: Asyhari, 2017)

The case study presented how the integrated use of modelling tools for flood hazard assessment, as well as damage and risk quantification, could be applied in the development of adaptation plans for reducing the negative impacts of coastal flooding due to extreme events.

As an example, a mix of structural as well as non-structural options reflecting a more holistic flood management approach was presented, including coastal flood adaptation measures such as the use of an online flood forecasting system, and contingency plans involving informed installation of temporary flood barriers based on forecasts.

Data availability was an important factor in the viability of the area as a test case. Long periods of atmospheric and sea level data were required, which were not uniformly available among the case study areas in the project. The timing of various tasks in the project was also a challenge to the holistic application of the different methods and tools developed. Some tasks fed into others, thus delays were propagated throughout the overall task schedules.

A variety of options is available for establishing a real-time forecasting system for an area. A system may be customised according to forecasting needs, stakeholder concerns, and data availability, and can thus be as streamlined or as complex as needed. In Greve, good availability of data with respect to forecasted model boundary inputs as well as flood model requirements allowed development of a state-of-the-art coupled 1D/2D hydrodynamic coastal flood model for the system. Application of several speed-up techniques also enabled use of this 1D/2D flood model in real-time forecasting.

Information dissemination needs in the case area were limited following local stakeholder demand. The municipality, utility company, and the citizens in the area did not actively participate in the case study, and required no interaction with the outcomes and deliverables of the PEARL project. Interaction with local stakeholders in the case study was limited to the utility company and municipality providing data for the case studies performed for the area. The Greve case area, from the project onset, was identified as a case area to be used more for the development, testing, and technical evaluation of tools and methods, and no stakeholder workshops were scheduled in the area.

Therefore, although facilities for automatic dissemination of forecast results were in place, the case study focused more on optimisation of the hydraulic forecast model with respect to simulation speed and accuracy, and on the development of a method for considering model uncertainty in the forecast system and result presentation.

LESSONS LEARNED, RESULTATER & DISKUSSION

Casestudiet præsenterede, hvordan den integrerede brug af modelleringsværktøjer til vurdering af oversvømmelsesrisici samt skade- og risikokvantificering kunne anvendes i udviklingen af tilpasningsplaner for at reducere de negative konsekvenser af kystnære oversvømmelser som følge af ekstreme begivenheder.

Som eksempel blev der fremlagt en blanding af strukturelle såvel som ikke-strukturelle muligheder, der afspejler en mere holistisk flodstyringsstrategi, herunder kystnære oversvømmelsestilpasningstiltag som brugen af et online oversvømmelsesprognosesystem og beredskabsplaner, der involverer informeret installation af midlertidig oversvømmelse barrierer baseret på prognoser.

Datatilgængelighed var en vigtig faktor i områdets levedygtighed som et testforløb. Der kræves lange perioder med data fra atmosfærisk og havniveau, som ikke var ensartet tilgængelige blandt case studieområderne i projektet. Tidspunktet for forskellige opgaver i projektet var også en udfordring for den holistiske anvendelse af de forskellige metoder og værktøjer, der blev udviklet. Nogle opgaver fodres ind i andre, således blev forsinkelser udbredt gennem de overordnede opgaveplaner.

En række muligheder er tilgængelige for etablering af et real-time prognosesystem for et område. Et system kan tilpasses efter forudsigelsesbehov, interessentproblemer og tilgængelighed af data og kan således være så strømlinet eller så kompleks som nødvendigt. I Greve muliggjorde god tilgængelighed af data med hensyn til prognostiserede modelgrænseindgange samt krav til oversvømmelsesmodeller udvikling af en state-of-the-art koblet 1D / 2D hydrodynamisk kystflodmodel til systemet. Anvendelse af flere speed-up teknikker muliggjorde også anvendelse af denne 1D / 2D oversvømmelsesmodel i real-time prognoser.

Behov for informationsformidling i sagen var begrænset efter lokal interessenters efterspørgsel. Kommunen, forsyningsselskabet og borgerne i området deltog ikke aktivt i casestudiet og krævede ingen interaktion med PEARL-projektets resultater og resultater. Interaktion med lokale interessenter i casestudiet var begrænset til brugsvirksomheden og kommune, der leverede data til de case-studier, der blev udført for området. Greve-sagen, fra projektets begyndelse, blev identificeret som et sagsområde, der skulle bruges mere til udvikling, testning og teknisk evaluering af værktøjer og metoder, og der blev ikke planlagt interessent workshops i området.

Selvom faciliteter til automatisk formidling af prognoseresultater var på plads, fokuserede case-undersøgelsen mere på optimering af den hydrauliske prognosemodel med hensyn til simuleringshastighed og -nøjagtighed og udvikling af en metode til at overveje modelusikkerhed i prognosesystemet og resultatpræsentation.

Concurrent Event Scenarios	Damage w/o Measures (million DKK)	Damage w/ Measures (million DKK)
100-yr Rainfall + 2-yr Storm Surge	1,160	439.4
2-yr Rainfall + 100-yr Storm Surge	1,800	405.2
100-yr Rainfall + 100-yr Storm Surge	2,105	566.5

Estimated flood damages from concurrent events with & without adaptation measures/ oversvømmelsesskade med & uden klimatilpasning (Source: Asyhari, 2017)

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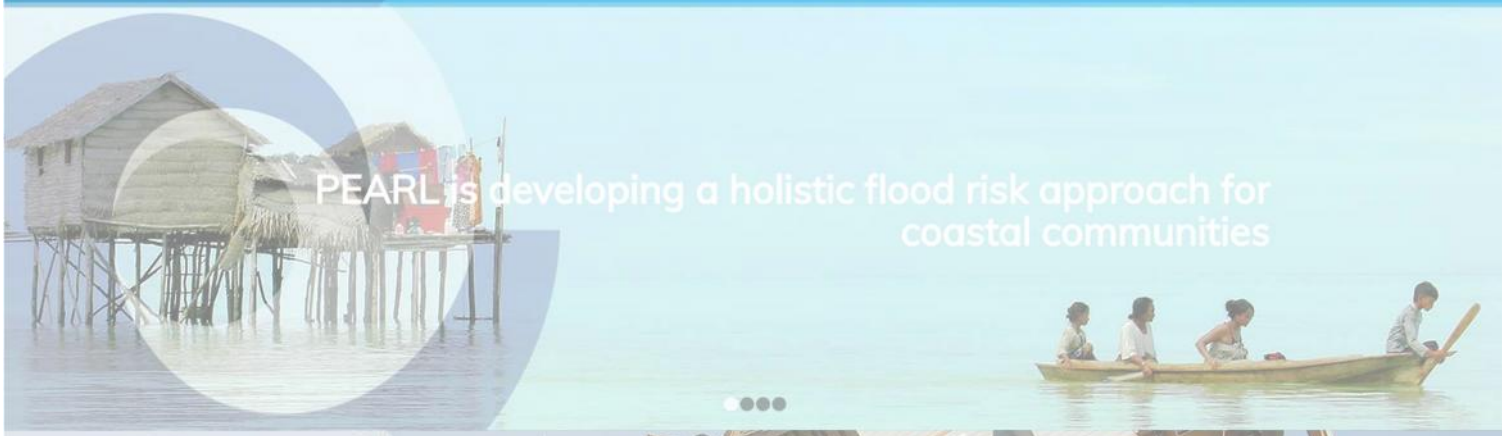
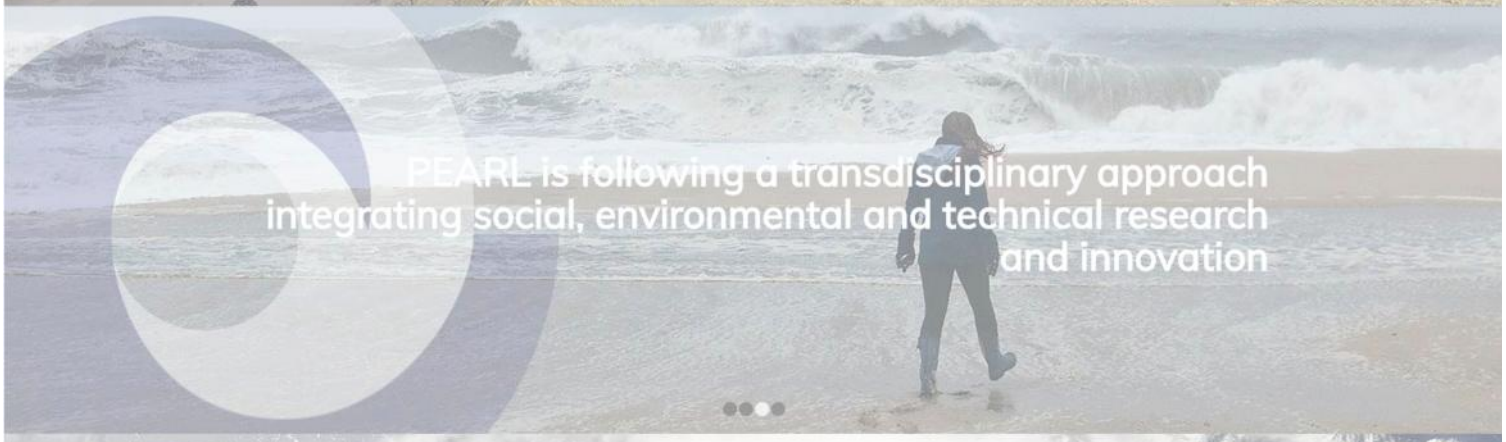
Preparing for Extreme And Rare events in coastaL regions

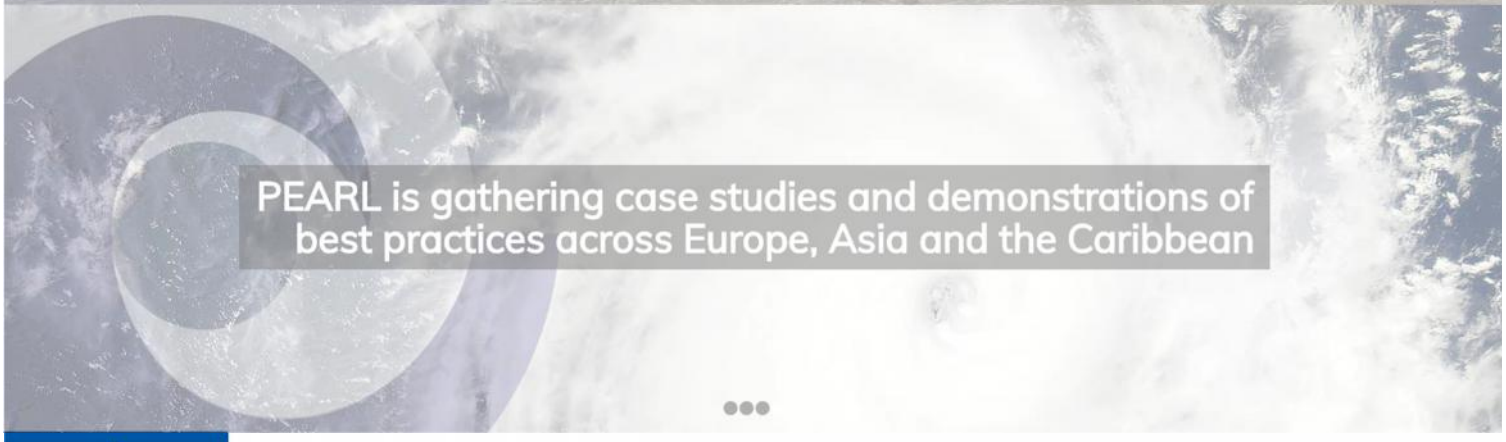


PEARL is developing a holistic flood risk approach for coastal communities

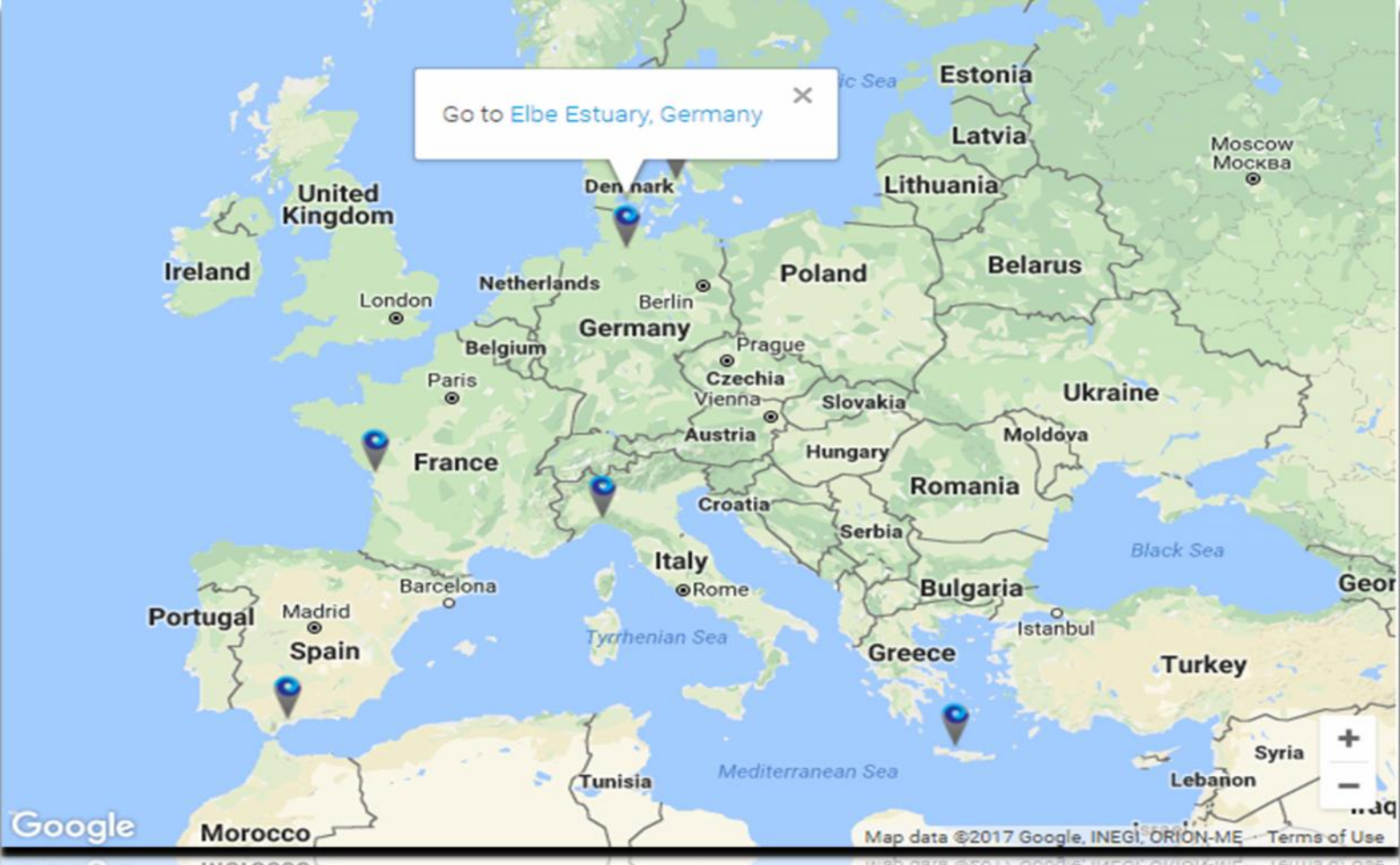
PEARL is improving forecasting, prediction and early warning capabilities



PEARL is following a transdisciplinary approach integrating social, environmental and technical research and innovation



PEARL is gathering case studies and demonstrations of best practices across Europe, Asia and the Caribbean



Risk Management Roadmap for the case study of Elbe Estuary, Germany

TUHH
Technische Universität Hamburg-Harburg

Hamburg University of Technology
Technische Universität Hamburg-Harburg

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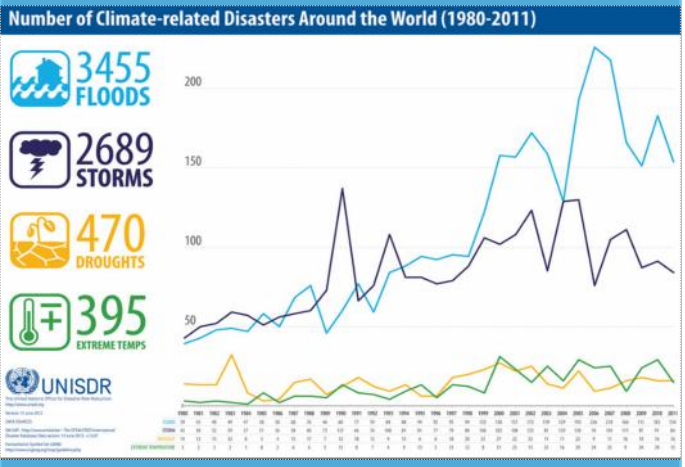
Preparing for Extreme And Rare events in coastaL regions

FLOOD RISK & FLOOD RISK MANAGEMENT

Flooding & Impact/ Überflutung & Folgen



Statistics / Statistiken

Flood Types / Hochwasserarten

Coastal floods are regarded as one of the most dangerous and harmful of all natural disasters. Rapid urbanisation in coastal areas combined with climate change and poor governance can lead to a significant increase in the risk of local pluvial flooding coinciding with high water levels in rivers and high tide or storm surges from the sea, posing a greater risk of devastation in coastal communities.

There is a need to improve forecasting, prediction and early warning capabilities using state of art science and technology to help policy makers and emergency services to develop robust risk reduction strategies. However, forecasting and prediction is only part of the answer. Of equal importance is the ability to effectively warn the population in areas that will be affected, and that warning systems for the general public are integrated into broader management strategies and supported by appropriate institutional and organisational arrangements. Preparing for effective response to extreme events not only involves technology but also significantly social, economic, organisational and political considerations.

Flood risk management aims to reduce the likelihood and/or the impact of floods. Experience has shown that the most effective approach is through the development of flood risk management programmes incorporating the elements of prevention, protections, preparedness, emergency response, recovery and lessons learned. Reducing human casualties and damage to economic activity and the environment are key objectives shared by all EU countries and implementation of the 2007 Floods Directive has an important role in making this happen.

The Directive applies to all kinds of floods (river, lakes, flash floods, urban floods, coastal floods, including storm surges and tsunamis) and it is being implemented in a three-base process i.e. the preliminary flood risk assessment, the development of floods hazard and flood risk maps and eventually the production of flood risk management plans. River basin Districts are the main units for the management of river basins, as described within the Water Framework Directive, therefore, they were adopted for the EU Flood Directive too.

Flood maps are being used by many different stakeholders within flood risk management and serve purposes related to prevention of the build-up of new risk, reduction of existing ones and adaptation to changing risk factors. Development and use of flood maps serves multiple purposes such as conduction of flood risk management plans, land use planning and land management, emergency planning, public awareness raising and within the private sector e.g. insurance assessment and pricing.

Floods, among others, are commonly referred to as natural disasters but they are not in fact the results of nature-related processes alone. They are to an ever-increasing extent directly attributable to various social, economic, historical, political and even cultural issues. The perception of flood impact on life and daily activities can be significantly different amongst the population and the level of knowledge and understanding of flood risk in a given area is directly related to people's decisions to either adjust their living to such a risk or simply to ignore it.

The PEARL project sought to fill in the lack of interaction between social aspects and technical measures – appearing to be a major hindrance for solving some of the greatest problems associated with floods and flood-related disasters.

HOCHWASSERRISIKO & HOCHWASSERRISIKOMANAGEMENT

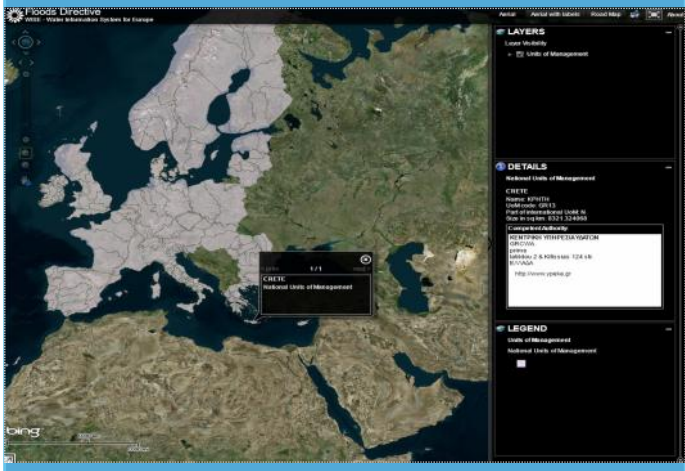
Extreme Sturmflutereignisse in Küstengebieten und Ästuaren stellen eine der gefährlichsten und bedrohlichsten Naturgefahren unserer Zeit dar. Das gleichzeitige Auftreten extremer Niederschlags- und Abflussereignisse kann die Gefährdung für die Küstengebiete noch verstärken. Daneben können Faktoren wie eine rasante Urbanisierung der Küstengebiete, mangelndes Gefahren- und Risikobewusstsein sowie der Klimawandel das Überflutungsrisiko für diese Gebiete noch erhöhen.

Um den Gefahren und Risiken solcher extremen hydrometeorologischen Ereignisse zu begegnen, müssen von den verantwortlichen politischen Entscheidungsträgern und Katastrophenschutzdiensten geeignete Handlungspläne und Maßnahmen entwickelt werden. Hier können effektive Vorhersage- und Frühwarnsysteme, auf dem neuesten Stand der Wissenschaft und Technik, einen wichtigen Beitrag leisten. Eine ebenso wesentliche Rolle spielt das effektive Informieren und Warnen der Bevölkerung in den potentiell gefährdeten Gebiete sowie die Einbindung dieser Frühwarnsysteme in übergeordnete Managementstrategien. Voraussetzung ist hier eine geeignete Zusammenarbeit der verantwortlichen Behörden und Institutionen. Zur Erarbeitung erfolgversprechender Maßnahmen und Handlungsplänen zur Begegnung von Extremereignissen müssen neben den technischen Aspekten auch gesellschaftliche, ökonomische, institutionelle sowie politische Aspekte berücksichtigt werden.

Hochwasserrisikomanagement versucht die Wahrscheinlichkeit und/oder die negativen Auswirkungen eines Hochwassers zu reduzieren. Die Erfahrungen der letzten Jahre hat gezeigt, dass erfolgversprechende Hochwasserrisikomanagementprogramme nur unter Berücksichtigung der Aspekte Vorbeugung, Schutz, Bereitschaft, Wiederherstellung, Gefahrenabwehr und Lessons learned entwickelt werden können. Die Anwendung der europäischen Richtlinie über die Bewertung und das Management von Hochwasserrisiken (2007/60/EG), spielt bei der Entwicklung von Hochwasserrisikomanagementplänen eine wesentliche Rolle. Die Reduzierung menschlicher Todesopfer, die Minderung ökonomischer Schäden sowie der Schäden an der Umwelt stellen hierbei Hauptziele der Richtlinie dar, die von allen Mitgliedsländern verfolgt werden. Die Umsetzung dieser EU-Richtlinie erfolgt in drei Phasen i) vorläufige Hochwasserrisikobewertung, ii) Entwicklung von Hochwasserrisikokarten, iii) Entwicklung von Hochwasserrisikomanagementplänen.

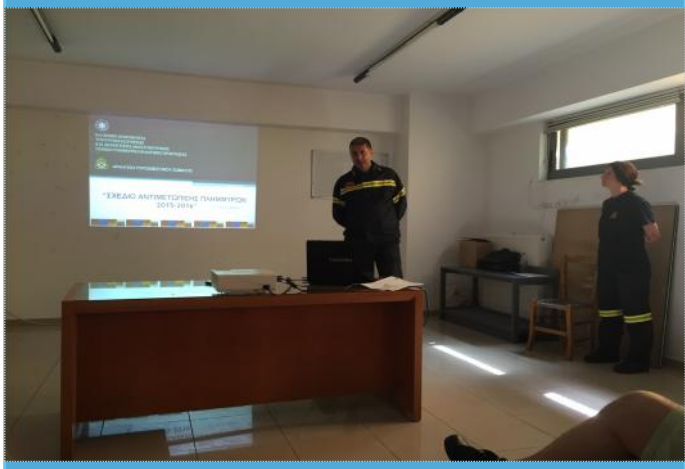
Im Rahmen des Hochwasserrisikomanagement werden Hochwasserkarten u.a. zur Abschätzung existierender und möglicher Risiken angewendet. Weiterhin dienen sie zur Entwicklung von Hochwasserrisikomanagementplänen und Katastrophenabwehrmaßnahmen sowie der Schaffung eines Gefahren- und Risikobewusstseins.

Das Projekt PEARL versucht die Lücke in der Interaktion zwischen gesellschaftlichen Gegebenheiten und technischen Maßnahmen, welche eine wesentliche Behinderung bei der Lösung von hochwasserbedingten Problemen darstellen, zu schließen



EU Flood Directive / Hochwasserrisikomanagementrichtlinie (2007/60/EC)

Implementation / Umsetzung



Management / Management

THE PEARL PROJECT: Methods & Tools

PEARL Project / Projekt PEARL

Case Studies / Projektgebiete

Partners / Projektpartner

The PEARL project, a collaborative research project with 4year duration, worked towards the development of adaptive, socio-otechnical risk management measures and strategies for coastal communities against extreme hydro-meteorological events minimising social, economic and environmental impacts and increasing the resilience of Coastal Regions in Europe. PEARL received funding from the European Union's Seventh Framework Programme for Research, Technological Development and Demonstration (EU-FP7) under the theme "Coasts at threat in Europe: tsunamis and climate-related risks" (ENV.2013.6.4-3).

The PEARL consortium consisted of 24 partners from 13 countries from Europe and Asia, with significant experiences of severe flood risk in coastal regions and advanced flood early warning systems. Project's leader was the UNESCO-IHE.

The project examined 6 case studies from across Europe and 5 pilots from the Caribbean and Asia. Those were:

- Greve, Denmark
- Elbe Estuary, Germany
- Les Boucholeurs, France
- Genoa, Italy
- Marbella, Spain
- Rethymno, Crete, Greece
- St. Maarten
- St. Lucia
- Tohoku, Japan
- Taiwan
- Ayutthaya, Thailand

The research activities which were conducted within the project provided a plethora of products i.e. methodological frameworks, tools and applications, as well as policy briefs and publications. The most indicative ones were:

- Risk and Root Cause Assessment framework
- Vulnerability assessment framework
- Innovative hazard assessment and modelling concepts for individual or combined extreme events and several scales
- Frameworks for impact/damages (direct/indirect, tangible/intangible), economic and public health impact assessment due to multiple causes and scenarios
- Toolkit for holistic/multiple risk and impact/damage assessment at strategic and operational levels
- Operational Early Warning Systems and new methodologies for their effective dissemination
- Novel methodologies and concepts for achieving faster simulations and for uncertainty propagation analysis
- Frameworks for stakeholders' analysis and engagement i.e. the Learning and Action Alliances
- Frameworks and tools for flood resilience assessment of urban systems
- Intelligent knowledge base for resilience measures and strategies and tools/algorithms supporting their selection
- Interactive web-based learning and planning platform
- Risk Management Roadmaps specifically tailored to case study needs
- Information system infrastructure for data and meta data management

All outcomes/products and their integration formed the holistic approach and eventually the PEARL holistic framework enhancing prevention, mitigation and preparedness capabilities and building flood resilience of coastal urban systems.

DIE PEARL INITIATIVE

http://www.pearl-fp7.eu/

Das übergeordnete Ziel des EU-Projektes PEARL ist die Entwicklung angepasster soziotechnischer Maßnahmen und Strategien für ein holistisches Risikomanagement um hydrometeorologischen Extremereignissen in Küstengebieten begegnen zu können und negative gesellschaftliche, ökonomische und ökologische Auswirkungen zu reduzieren und gleichzeitig die Resilienz der Küstengebiete zu erhöhen. Das Projekt PEARL wurde im Rahmen European Union's 7th Framework Programm for Research, Technological Development and Demonstration (EU-FP7) unter der Thematik „Coasts at threat in Europe: tsunamis and climate-realted risks" (ENV.2013.6.4-3).

Das Projektkonsortium bestand aus 24 Partnern aus 13 europäischen und asiatischen Ländern, die umfangreiche Erfahrungen auf dem Gebiet der Risikobewertung und Frühwarnsystemen. Die Projektkoordination oblag UNESCO-IHE.

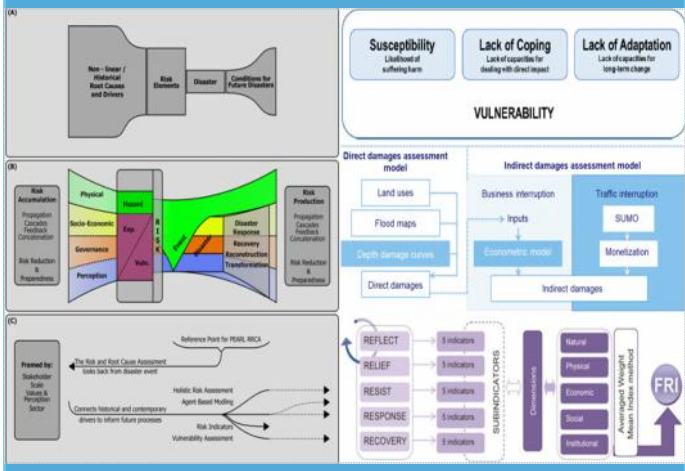
Im Ganzen bearbeiteten die Projektpartner 6 Projektgebiete in Europa und 5 Projektgebiete in der Karibik sowie in Asien:

• Greve, Dänemark	• St. Martin
• Elbeästuar, Deutschland	• St. Lucia
• Les boucholeurs, Frankreich	• Tohoku, Japan
• Genua, Italien	• Taiwan
• Marbella, Spanien	• Ayutthaya, Thailand
• Rethymno, Kreta, Griechenland	

Im Rahmen der durchgeführten Forschungsarbeiten wurden eine Vielzahl von Produkten entwickelt, welche in Kombination dem holistischen Ansatz der Risikobewertung zur Förderung der Katastrophenvorbeugung, -mitigation und Verstärkung der Hochwasserresilienz urbane Systeme in Küstengebieten folgen:

- Risk and Root Cause Assessment Framework
- Vulnerability Assessment Framework
- Innovative Gefahrenanalyse- und Modellierungskonzepte für Einzelereignisse und kombinierte Ereignisse auf verschieden Skalen
- Konzepte für die Bewertung von Schäden (direkt/indirekt, tangibel/intangibel) und Auswirkungen auf Ökonomie und die öffentliche Gesundheit aufgrund verschiedenen Gefahren und für verschiedenen Szenarien
- Werkzeugkasten für holistische/multiple Risiko- und Schadensbewertung auf einem strategischen und operationalem Level
- Operationelle Frühwarnsysteme und neue Methoden für deren effektive Dissemination
- Neue Methoden und Konzepte für schnelle Simulation und Analyse der Unsicherheiten
- Konzepte für die Stakeholderanalyse und –beteiligung, z.B. Lern- und Aktionsallianzen
- Konzepte und Werkzeuge für die Bewertung der Hochwasserresilienz urbaner Gebiete
- Umfassende Wissensbasis für Resilienzmaßnahmen und -strategien, Werkzeuge und Algorithmen zu deren Auswahl
- Interaktive Webbasierte Lern- und Planungsplatform
- Risikomanagement Roadmaps, angepasst an die speziellen Bedingungen in den Pilotgebieten
- Informationssysteme für Daten und Metadaten

DAS PROJEKT PEARL: Methoden & Werkzeuge



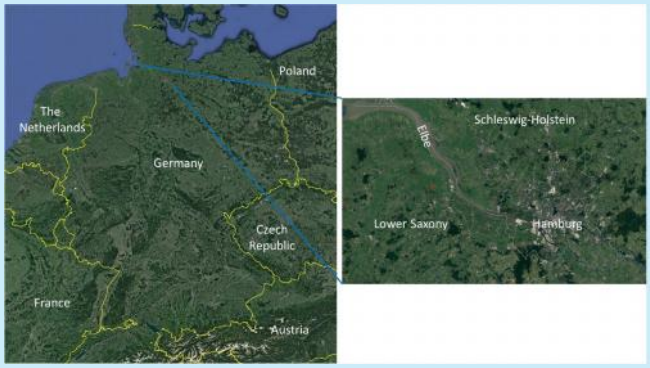
Methodologies / Methoden

Tools & Application / Werkzeuge & Anwendungen

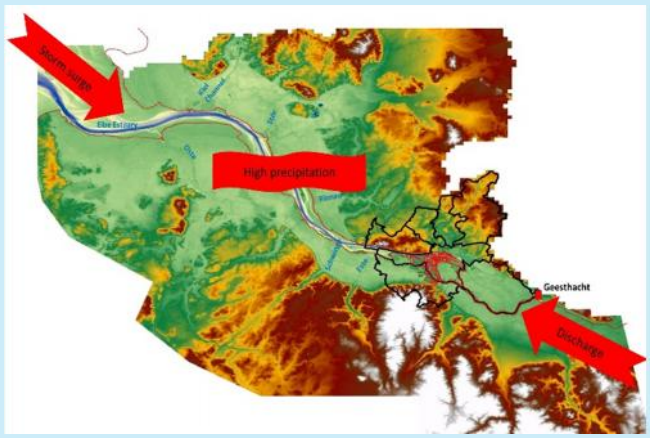
Publications & Policy Briefs / Publikationen & Policy Briefs

CASE STUDY OVERVIEW

PROBLEM DESCRIPTION, ISSUES & CHALLENGES



Location of the project area / Lage des Projektgebiets



Hazards of the project area/ Gefahren in dem Projektgebiet

Flood prone area / Überflutungsgefährdetes Gebiet

The case study area of the Elbe estuary with its largest urban area being the city of Hamburg is located in the North German Plain. The case study area covers the Elbe river section between the weir in Geesthacht and the Elbe mouth towards the North Sea. Due to the geographical orientation with a direct connection to North Sea, extreme winds and storms coming from westerly and north-westerly directions can lead to severe storm surges with extreme water levels. The most devastating storm surge, which caused large damages and a large number of casualties in the Elbe estuary occurred on February 16th/17th, 1962. Strong winds (Beaufort scale 9-10) caused extreme water levels leading to dike breaches in many places along the Elbe river. The Hamburg District Wilhelmsburg was worst affected by this extreme storm event. 222 people lost their lives due to the inundations as a result of the dike breaches. This example illustrates one of the hazards relevant for the case study area.

On the other hand side, high precipitation in the case study area or the upstream part of the Elbe catchment area can lead to higher river discharge posing an additional threat to the hinterland. Estuarine floods caused by extreme storm surges and high precipitation, including floods caused by the failure of the flood protection infrastructure, must be regarded as the predominant hazards to the Elbe estuary and the city of Hamburg.

Due to the present and future development of the natural and social boundary conditions, an increased probability and consequences of flooding of the hinterland can be anticipated. By dint of the change of the climatic conditions, an increase of the sea level can be anticipated, as well as an increase of storm events (frequency and intensity) and extreme hydrological loads because of high precipitation.

On the social and economic side, one has to cope with growing urbanisation and high utilisation pressure. More and more people are moving to the suburbs. The urban areas are subjected to a constant urban development, to create residential and living space for the people on the one hand. Simultaneously, the infrastructure systems of the urban area (traffic/transportation, energy supply, water and food supply, healthcare, finance and insurance, IT and media) develop in order to accommodate the rising number of new residents. Alongside, commercial and industrial areas develop, which contribute to the economic importance of the city area. In the scope of the urban development, monetary values are created, which represents additional risk elements within the flood prone areas.

A specific feature of the Elbe river can be found on the regulatory side. On the German territory the Elbe river flows through several federal states having their own policies and regulations, which must not inevitably be coordinated or harmonized. In the case study area the federal states i) Lower Saxony, ii) Schleswig-Holstein and iii) Hamburg are responsible for the management of the Elbe river section. Corresponding to their different policy making towards the climate change adaptation an unbalanced risk distribution in the entire estuary system, which is governed within several administrative units, occurs.

PILOTGEBIET ÜBERBLICK

Das Projektgebiet liegt in der Norddeutschen Tiefebene und umfasst den Flussabschnitt der Elbe zwischen dem Wehr in Geesthacht und der Mündung der Elbe in die Nordsee. Aufgrund der geographischen Lage und geographischen Ausrichtung mit einer direkten Verbindung zur Nordsee, stellen Starkwinde und Stürme aus westlichen bis nordwestlichen Richtungen eine ernstzunehmende Gefahr dar, welche zu Sturmfluten entlang der Elbe führen können. Die verheerendste Sturmflut der Neuzeit traf das Elbeästuar und die Stadt Hamburg im Januar 1962. Starke Winde mit Windstärken von 8-9 auf der Beaufortskale führten zu extrem hohen Wasserständen entlang der Elbe, welche zahlreiche Deichbrüche zur Folge hatten. Der Hamburger Stadtteil Wilhelmsburg war dabei am schwersten betroffen. 222 Menschen verloren in den Fluten ihr Leben. Dieses Beispiel soll eine der Gefahren für das Elbeästuar illustrieren.

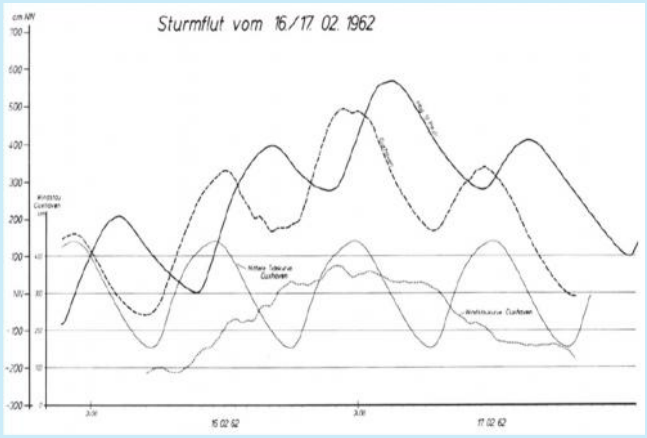
Auf der anderen Seite können Starkniederschläge über dem Projektgebiet oder weiter Oberstrom im Einzugsgebiet der Elbe zu hohen Abflüssen in der Elbe führen, die eine weitere Gefahr für das Projektgebiet darstellen. Hochwasser im Ästuargebiet einschließlich Überschwemmungen aufgrund des Versagens von Hochwasserschutzbauwerken stellen die wesentlichen Gefahren für das Elbeästuar und die Stadt Hamburg dar.

Aufgrund der gegenwärtigen und zukünftigen Entwicklungen der natürlichen und gesellschaftlichen Randbedingungen, kann eine Erhöhung der Wahrscheinlichkeit und der Konsequenzen von Hochwassern gerechnet erwartet werden. Durch die Veränderungen der klimatischen Bedingungen muss mit einem Anstieg des Meeresspiegels gerechnet werden. Darüber hinaus ist es wahrscheinlich, dass es zu einer Intensivierung und einem häufigeren Auftreten von Sturmereignissen und extremen hydrometeorologischen Ereignissen kommen wird.

Auf der anderen Seite hat man es mit einem wachsenden Nutzungsdruck aufgrund der steigenden Urbanisierung zu tun. Immer mehr Menschen in das Hinterland entlang der Elbe. Gleichzeitig entwickelt sich die Infrastruktur (Verkehr/Transport, Energieversorgung, Wasserver-/entsorgung, Nahrungsmittelversorgung, Gesundheitswesen, Banken- u. Finanzwesen, digitale Infrastruktur) der Region um den wachsenden Bedürfnissen der Gesellschaft gerecht zu werden. Daneben entwickeln sich genauso die Gewerbe- und Industriestandorte. Dadurch werden monetäre Werte geschaffen, die einen Beitrag zur Erhöhung des Überflutungsrisikos leisten.

Eine Besonderheit des Projektgebietes stellt die hoheitliche Situation dar. Auf deutschem Gebiet fließt die Elbe durch mehrere Bundesländer, die ihre eigenen Gesetze und Verwaltungsstrukturen haben. Im Projektgebiet sind die Bundesländer Schleswig-Holstein, Niedersachsen und die Freie und Hansestadt Hamburg für die Bewirtschaftung und das Management der Elbe zuständig. Aufgrund der unterschiedlichen Politikgestaltung mit Blick auf die Anpassung an den Klimawandel und den unterschiedlichen Verwaltungsstrukturen, kommt es zu einer ungleichen Verteilung des Risikos entlang der Elbe.

PROBLEMSTELLUNG & HERAUSFORDERUNGEN



1962's Storm surge hydrograph / Ganlinie der Sturmflut 1962

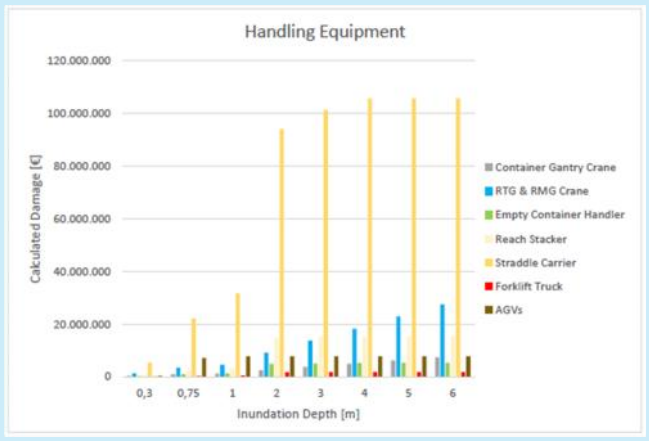
Flooding of Wilhelmsburg 1962 / Überflutungen in Wilhelmsburg 1962

Dike breach at the Lühe 1962 / Deichbruch an der Lühe 1962

PEARL OUTCOMES

Representative house types in Hamburg Wilhelmsburg / Musterhaustypen in Hamburg Wilhelmsburg

Storm surge 2007 - Hafen City / Sturmflut 2007 – Hafen City



Damages to handling equipment in sea ports / Schäden an Hebe- und Transportgeräten in Seehäfen

The Elbe estuary and the city of Hamburg, located in the North German Plain with a direct connection to the North Sea have to face the threat of extreme wind and storms leading to storm surges in the Elbe river. Especially, extreme winds from westerly and north-westerly directions cause storm surges with extreme water levels along the Elbe river. In the past, a number of storm surges occurred in the Elbe estuary causing different magnitude of impacts. Due to this experience, there is a certain awareness of flood risk of the public and the stakeholder. In the aftermath of the most devastating extreme event of the recent past, being the storm surge in January 1962, the entire flood protection infrastructure along the Elbe river and in the city of Hamburg was redesigned and heightened to withstand the storm surged coming from the North Sea. Since then, the flood protection infrastructure has been constantly adjusted to the ever changing environmental conditions, being nowadays on a high safety level.

The wide variety of research activities performed in the PEARL project, focussed on the further enhancement of the flood protection strategies and flood risk management plans. For this purpose, a bunch of tools and methods for a holistic flood risk assessment and management have been developed in close collaboration with the key stakeholder of the Elbe estuary, respectively the city of Hamburg.

The research activities started with the investigation of past extreme events in the project area, their impacts and the environmental, technical and social boundary conditions in the project area to understand the formation of vulnerability and risk in this area. The formation of hazards in the project area has been investigated by statistical analyses of hydro-meteorological extreme events The developed statistical models have been applied to derive extreme event scenarios as input for the further research activities. A 2D hydrodynamic numerical model of the Elbe estuary has been set-up to simulate the impacts of extreme event scenarios. The results of the simulations of hazards are the input for the holistic and multiple risk assessment. The temporal evolution of the flood risk in the built environment has been assessed, to investigate the influence of the urban and societal development on the formation of the flood risk. In close collaboration with the BSH TUHH developed a water level forecast system based on the 2D hydrodynamic numerical model for the entire Elbe estuary which uses pointwise water level forecasts of the BSH as input. TUHH's water level forecast system extends the pointwise available water level forecast of the BSH into a flat forecast of the water levels for the entire estuary. Furthermore, TUHH developed an evacuation model for the Hamburg district Wilhelmsburg. At present the evacuation models covers the pedestrian evacuation and the evacuation of people by public transport.

The key results and developments i) tailored stakeholder involvement, ii) water level forecasting system for the Elbe estuary, iii) flood risk management & evacuation, iv) analysis of possible adaptation measures and v) hazard assessment and storm surge generator are described in the following sections (Activity 1 to Activity 5) in more detail.

PILOTGEBIET ÜBERBLICK

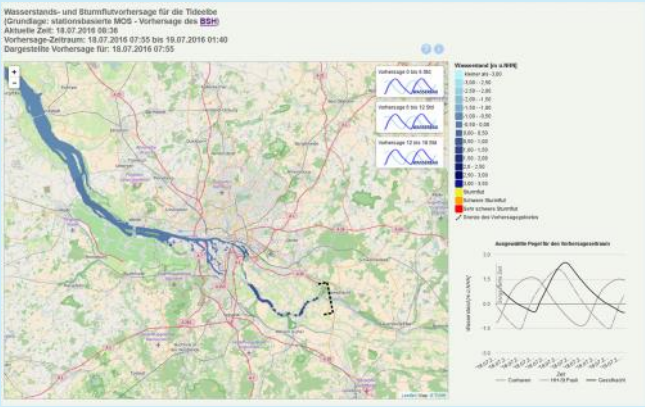
Starkwind und Stürme aus westlichen und nordwestlichen Richtungen stellen für die Hansestadt Hamburg und das Elbeästuar mit seiner direkten Verbindung zur Nordsee eine ernstzunehmende Bedrohung dar. Sturmfluten im Elbeästuar führten in der Vergangenheit zu Überschwemmungen unterschiedlichen Ausmaßes. Aufgrund der Erfahrungen der Bevölkerung und der Behörden mit den Sturmfluten und Überschwemmungen, entwickelte sich über die Jahre ein ausgeprägtes Risikobewusstsein für Sturmfluten als Gefahr für Leib und Leben. In den Jahren nach der verheerenden Sturmflut von 1962 wurde der gesamte Hochwasserschutz entlang des Elbeästuars und der Stand Hamburg erneuert und regelmäßig verstärkt um den sich stetig ändernden Umweltbedingungen zu widerstehen.

Die im Projekt durchgeführten Arbeiten, konzentrierten sich auf die Entwicklung Methoden und Werkzeugen zur Unterstützung der bereits existierenden Hochwasserschutzstrategien und der Hochwasserrisikomanagementplänen. Dabei erfolgte die Entwicklung der Methoden und Werkzeuge in enger Zusammenarbeit mit den relevanten und für den Hochwasserschutz verantwortlichen Behörden und Interessenvertretern.

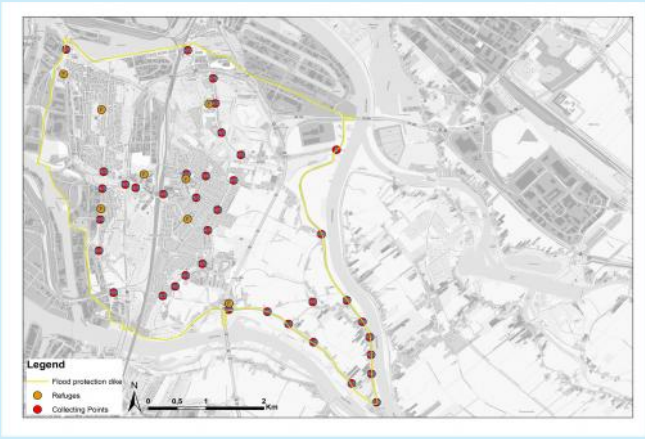
Die durchgeführten Arbeiten deckten dabei die Aspekte der holistischen Risikobetrachtung ab. Einerseits wurden Sturmflut- und Überschwemmungsereignisse der Vergangenheit im Hinblick auf das Ausmaß und die Manifestation ihrer Auswirkungen vor einem gesellschaftlichen, technischen, ökonomischen und einem umweltbezogenen Hintergrund untersucht. Ziel war es einerseits Aussagen über die Ursachen und Entwicklungen, die zu der Manifestation der Auswirkungen der Sturmfluten wie sie in der Vergangenheit aufgetreten sind, treffen zu können. Und andererseits entsprechende Aussagen über zukünftige Entwicklungen treffen zu können. Die Entstehung von Gefährdungen im Elbeästuar wurde mit Hilfe statistischer Analysen hydrometeorologischer Extremereignisse untersucht. Auf Grundlage eines zwei dimensionalen hydrodynamisch numerischen Modells des Elbeästuars wurden die Entwicklung und Auswirkungen von Extremereignisse im Elbeästuar untersucht. Die Ergebnisse dieser Simulationen bildeten u.a. die Grundlage für die Untersuchung der Hochwasserschäden und des Hochwasserrisikos im Projektgebiet. Hier wurde unter anderem die zeitliche Entwicklung des Hochwasserrisikos auf Grund einer sich entwickelnde urbanen Umgebung untersucht. In enger Zusammenarbeit mit dem BSH wurde ein Wasserstandsvorhersagemodell entwickelt, welches die punktuellen Wasserstandsvorhersagen des BSH in eine flächenhafte Vorhersage der Wasserstände für das gesamte Ästuargebiet transformiert. Weiterhin wurde ein Evakuierungsmodell für den Stadtteil Wilhelmsburg entwickelt, welches zum jetzigen Zeitpunkt die Evakuierung von Fußgängern und die Evakuierung der Bevölkerung mit öffentlichen Verkehrsmittels simuliert. Ziel war die Erforschung der Möglichkeiten einer hybriden GPU/CPU Simulation zur Beschleunigung der Simulationsgeschwindigkeit.

Die Kernergebisse und –entwicklungen i) angepasste Beteiligung von Interessensvertretern, ii) Wasserstandsvorhersagemodell für das Elbeästuar, iii) Hochwasserrisikomanagement & Evakuierung, iv) Analyse möglicher Anpassungsmaßnahmen u. v) Gefährdungsanalyse und Sturmflutgenerator werden in den Abschnitten Aktivität 1 bis Aktivität 5 näher beschrieben.

PEARL ERGEBNISSE



Operational Elbe model & Forecasting model / Operationelles Elbemodell & Vorhersagemodell



Collecting Points & Refuges in Wilhelmsburg / Sammelstellen & Fluchtburgen in Wilhelmsburg

Tailores Stakeholder Engagement / Angepasste Beteiligung der Interessensverreter

THE ROLE OF LAAs, STAKEHOLDERS' & CITIZENS' PARTICIPATION

Stakeholder workshop IBA Lab / Stakeholder Workshop IBA Labor

Stakeholder discussions IBA Lab/ Stakeholderdiskussion IBA Labor

Bilateral stakeholder meeting TUHH/BSH / Bilateres Stakeholdertreffen TUHH/BSH

Learning and Action Alliances (LAAs) can be regarded as "a group of individuals or organisations with a shared interest in innovation and scaling-up of innovations, in a topic of mutual interest" (Batchelor and Butterworth 2008), with the aim create possible actions to achieve a certain goal. The main output of the LAAs is knowledge (Wenger 2000), which is coupled to social interactions, that bring stakeholder into relationship with each other and responses at stake (van Heerk et al. 2011). By this, it is possible to create and take practice-driven policy processes, informed by a process of multi-stakeholder knowledge.

In the scope of the PEARL project a LAA is a convention of individuals and/or organisations who are involved in or effected by decision making processes and their outcome in the context of coastal risk and/or disaster management, risk related spatial planning or any other political and economic decisions that could alter the group members situation or capacities before, during or after an extreme event.

As the Elbe estuary or its parts have been addressed in a number of national and international projects, information about the main stakeholder and their involvement has been collected. The main stakeholders of the Elbe estuary can be summarized as:

- The Agency for Roads, Bridges and Waterways (LSBG)
- Ministry of Interior Affairs (BIS)
- Hamburg Port Authority (HPA)
- Agency for Coastal Protection, National Resources and Sea Protection, Schleswig-Holstein (LKN-SH)
- Federal Maritime and Hydrographic Agency (BSH)
- Federal Waterways and Research Institute (BAW)
- Waterways and Shipping Office – Hamburg (WSA)
- German Association for the Protection of Nature (NABU)
- Friends of the Earth (BUND)
- World Wide Fund for Nature (WWF)
- Dike Associations
- Private Stakeholder

Based on an analysis of their influence and relevance (stakeholder analysis) for the flood risk management in the Elbe estuary the following key stakeholders have been selected:

- The Agency for Roads, Bridges and Waterways (LSBG)
- Ministry of Interior Affairs (BIS)
- Hamburg Port Authority (HPA)
- Federal Maritime and Hydrographic Agency (BSH)

A brief description of the key stakeholders can be found in the next section (Parties involved).

Due to the specific features of the stakeholder involvement in the case study area, local culture and the level of risk awareness, the overall concept for LAAs has been adjusted to accommodate the local needs. The concept of has been shifted away from bigger lengthy open sessions and workshops towards a more tailored approach in which the key stakeholders are directly addressed in (regular) face-to-face meetings (see section Tailored Stakeholder Involvement).

DIE ROLLE DER LAAS, INTERESSENSVERTRETER & BÜRGERBETEILIGUNG

Lern- und Aktionsallianzen (LAAs) sind “Gruppen von Individuen oder Organisationen mit einem gemeinsamen Interesse an Innovationen oder der Übertragung von Innovationen auf einem gemeinsamen Interessensgebiet“ (Batchelor and Butterworth 2008), mit dem Ziel Maßnahmen oder Prozesse anzustoßen und zu vereinbaren um eine bestimmtes Ziel zu erreichen. Mit Hilfe dieser Lern- und Aktionsallianzen wird Wissen bei den Teilnehmern generiert, verbunden mit sozialer Interaktion, die die Interessensvertreter in Beziehung zu einander setzen und entsprechenden Handlungen zur Folge haben (van Heer et al. 2011). Es wird möglich, praxisorientierte politische Prozesse auf Grundlage eines Multistakeholderwissens anzustoßen.

Im Rahmen des Projektes PEARL sind Lern- und Aktionsallianzen eine Zusammenkunft von Individuen und/oder Organisationen, die an Entscheidungsprozessen und ihren Ergebnissen bzgl. des Hochwasserschutzes und/oder des Hochwasserrisikomanagements in Küsten- und/oder Ästuargebieten beteiligt oder von ihnen betroffen sind.

Um einen Überblick über die Vielfalt an Interessensvertretern und ihren Zuständigkeiten im Projektgebiet zu gewinnen wurden entsprechenden Informationen zusammengetragen. Die folgende Liste stellt die Interessensvertreter und Akteure zusammen:

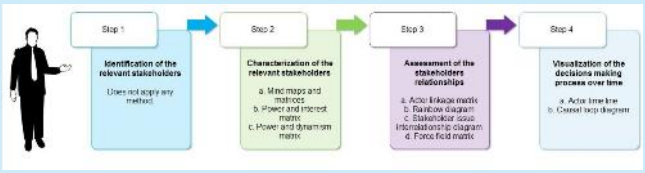
- Landesbetrieb für Straßen, Brücken und Gewässer (LSBG)
- Behörde für Inneres und Sport (BIS)
- Hamburg Port Authority (HPA)
- Landesbetrieb für Küstenschutz, Nationalpark und Meeresschutz Schleswig-Holstein (LKN-SH)
- Bundesamt für Seeschifffahrt und Hydrographie (BSH)
- Bundesanstalt für Wasserbau (BAW)
- Wasser- und Schifffahrtsämter
- Naturschutzbund Deutschland (NABU)
- Bund für Umwelt und Naturschutz Deutschland (BUND)
- World Wide Fund for Nature (WWF)
- Deichverbände
- Private Interessensvertreter

Auf Grundlage einer Stakeholderanalyse wurden die relevanten Akteure ausgewählt:

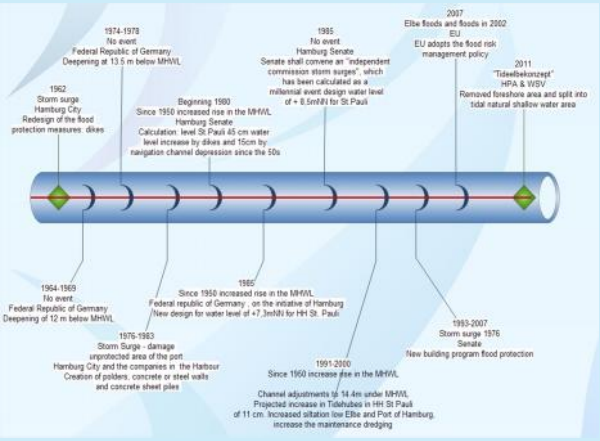
- Landesbetrieb für Straßen, Brücken und Gewässer (LSBG)
- Behörde für Inneres und Sport (BIS)
- Hamburg Port Authority (HPA)
- Bundesamt für Seeschifffahrt und Hydrographie (BSH)

Eine kurze Beschreibung der Institutionen findet sich im folgenden Abschnitt.

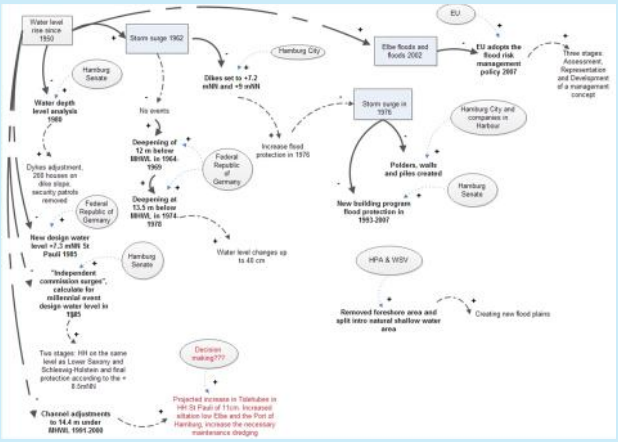
Infolge der intensiven Einbeziehung der Akteure und Interessensvertretern in bisherigen Projekten und Initiativen, sowie dem hohen Maß an Risikobewusstsein, wurde das Konzept der LAA weiterentwickelt, weg von zeitaufwendigen Veranstaltungen mit einer Vielzahl von Akteuren hin zu einen auf die Bedürfnisse und Interessen spezifischer Akteure angepassten Ansatz der LAA (siehe Angepasste Beteiligung der Akteure).



Method of stakeholder analysis / Ablauf der Stakeholderanalyse



Actor time line / Zeitstrahl der Akteursentscheidungen



Causal loop diagram / Ursachen-/ Entscheidungsdiagramm

PARTIES INVOLVED

Elbe mouth / Elbmündung

Elbe River / Elbe

Panorama Elbe & Landungsbrücken / Panorama Elbe & Landungsbrücken

The Agency for Roads, Bridges and Waters (LSBG):
The Agency for Roads, Bridges and Waters (LSBG) as the service provider of the ministries and the authorities is responsible for the construction and needs-based maintenance of technical infrastructure of the Free and Hanseatic City of Hamburg (LSBG, n.d.). Contracting authorities of the LSBG are the Ministry of Environment and Energy (BUE) and the Ministry of Economy, Traffic and Innovation. The LSBG assumes responsibility for the planning, design, construction (project management), maintenance and operation of the technical infrastructure regarding the public flood protection, among other things (lsbg.hamburg.de/np-aufgabe/).

Hamburg Port Authority (HPA):
In 2005, the Hamburg Port Authority was established as a public agency, which acts on the private commercial sector on the one hand and which takes sovereign tasks concurrently. Among other things, HPA is responsible for the flood protection in the harbour area and the tidal reaches in front of the flood protection dikes, which are maintained by the LSBG. The Hamburg Port Authority cooperates closely with the LSBG with regard to the flood protection. Additionally, the authority is in charge to grant financial support for the structural private flood protection in the tidal reaches in front of the public flood protection dikes and the Hafen City. Owner, leaseholder or tenants of plots in the mentioned areas, who are e.g. harbour terminal operator, can apply for the financial support (*https://www.hamburg-port-authority.de/*)

Federal Maritime and Hydrographic Agency (BSH):
The Federal Maritime and Hydrographic Agency is an agency within the remit of the Federal Ministry of Transportation, Building and Urban Development. Among other things, the BSH provides forecasting and warnings services to shipping, port authorities and vessel traffic services with its marine forecasts (BSH n.a.). Furthermore, the BSH delivers storm surge warnings, to the authorities responsible for emergency response in case of storm surges, namely the Ministry or Internal Affairs (BIS).

Ministry of Interior Affairs (BIS):
The Ministry of Interior Affairs is responsible for the superior coordination of the flood protection in Hamburg. In case, that water levels higher than +5mNN are anticipated (forecasted by the BSH), a central emergency response task force (Zentraler Katastrophendienststab, ZKD) is set up in the premises of the BIS. Employees of the BIS and representatives of the fire brigade, Federal Agency for Technical Relief (THW), German Meteorological Services, urban transportation (Hochbahn AG, S-Bahn Hamburg GmbH) and the LSBG forming this task force responsible the management and coordination of the emergency response measure. The state council of the Ministry of Interior Affairs is the head of this task force. Pooling the relevant incoming information and the proclamation of respective water level stages, in dependency of the forecasted water levels of the BSH, are further tasks of the task force. (Hamers 2017)

BETEILIGTE AKTEURE

Landesbetrieb Straßen, Brücken und Gewässer (LSBG):
Der Landesbetrieb Straßen, Brücken und Gewässer ist als Dienstleister der Behörden und Ämter verantwortlich für die Realisierung und die bedarfsgerechte Erhaltung baulicher Anlagen der technischen Infrastruktur in der Freien und Hansestadt Hamburg. Die auftraggebenden Diensststellen sind die Behörde für Umwelt und Energie (BUE) und die Behörde für Wirtschaft, Verkehr und Innovation (BWVI). Der LSBG übernimmt u.a. die Verantwortung für die Planung, den Entwurf, den Bau (Projektsteuerung), die Unterhaltung und das Betreiben des öffentlichen Hochwasserschutzes. (lsbg.hamburg.de/np-aufgabe/)

Hamburg Port Authority (HPA):
Seit dem Jahr 2005 übernimmt die Hamburg Port Authority neben Ihren privatwirtschaftlichen Aktivitäten auch hoheitliche Aufgaben im Bereich des privaten Hochwasserschutzes. Die HPA ist unteranderem für den Hochwasserschutz im Hafenbereich und den Tidegebieten der Elbe vor der öffentlichen Hochwasserschutzlinie, welche der Hoheit des LSBG unterliegt, verantwortlich. Zwischen der HPA und dem LSBG besteht eine enge Zusammenarbeit auf dem Gebiet des Hochwasserschutztes. Die HPA ist darüber hinaus der Ansprechpartner für Förderungen im Rahmen des privaten Hochwasserschutzes. Es können bei der HPA finanzielle Unterstützungen zur Realisierung technischer Hochwasserschutzmaßnahmen in den Hafengebieten sowie in den tidebeeinflussten Gebieten vor der öffentlichen Hochwasserschutzlinie beantragt werden. Förderungen können durch Eigentümer, Pächter oder Mieter von Grundstücken im Tidegebiet der Elbe beantragt werden.

(*https://www.hamburg-port-authority.de/*)
Bundesamt für Seeschifffahrt und Hydrographie (BSH):
Das Bundesamt für Seeschifffahrt und Hydrographie ist eine Behörde im Geschäftsbereich des Bundesministeriums für Verkehr, Bau und Stadtentwicklung mit Dienststellen in Hamburg und Rostock. Das BSH unterstützt mit meereskundlichen Vorhersagen für die deutsche Nord- und Ostseeküste die Schifffahrt, Hafenämter und Verkehrszentralen. Es liefert unter anderem aktuelle Wasserstandsvorhersagen, Gezeitenvorausberechnungen oder Informationen zu Seegang oder Eisverhältnissen. Darüber hinaus gibt das BSH Warnungen vor Sturmfluten heraus, auf deren Grundlage die verantwortlichen Behörden (BIS) Maßnahmen und Abläufe zum Schutz der Bevölkerung und zur Gefahrenabwehr vor den Sturmfluten koordinieren.

Behörde für Inneres und Sport (BIS):
Die Behörde für Inneres und Sport übernimmt die übergreifende Koordination des Hochwasserschutzes und im Katastrophenfall (z.B. Evakuierung im Sturmflutfall) die Leitung der Einsatzkräfte. Ist ein Wasserstand von über 5mNN zu erwarten, wird ein Zentraler Krisendienststab, der Einsatz der Hilfskräfte koordiniert, eingerichtet. Mitarbeiter der Behörde für Inneres und Sport sowie Vertreter der Feuerwehr, des Technischen Hilfswerkes (THW), des Deutschen Wetterdienstes (DWD), der Hochbahn AG, S-Bahn Hamburg GmbH und des LSBG bilden den Zentralen Krisendienststab. Die Aufgaben des zentralen Krisendienststabes umfassen die Koordination der Einsatzkräfte, das Bündeln der eingehenden Information und das Ausrufen der jeweiligen Wasserstandsstufen. Notfallmaßahmen werden entsprechend den Wasserstandsstufen eingeleitet.

Aerial view Hafen City / Luftbild Hafen City

Flood Protection Hafen City / Hochwasserschutz Hafen City

Hamburg sea port / Hamburger Seehafen

ACTIVITY 1: Tailored Stakeholder Involvement

Elbe at Kollmar / Elbe bei Kollmar

Elbe at Lühe / Elbe bei Lühe

Elbe island Neuwerk / Elbinsel Neuwerk

In the past, several extreme events hit the Elbe estuary and the city of Hamburg (e.g. …, 1825, 1855, 1962, 1976). During the storm surge event of 1962 several dike breaches occurred along the Elbe estuary and the city of Hamburg causing large scale inundations of the hinterland and a large number of human casualties, representing the most devastating event in the recent past. The authorities and the public became aware of the storm surges as a serious risk and threat, which must not be underrated. On the part of the authorities and stakeholder, this event led to a rethinking and a redesign of the flood protection infrastructure.

The specific situation and features to the Elbe estuary case study are furthermore related to the intensive engagement of the key stakeholders in previous initiatives and participatory planning actions undertaken within several national and international projects (BMBF KLIMZUG-Nord, XtremRisk, Corfu). The experience obtained in those projects has been taken as a baseline for the LAA development. Building up on this experience, a more tailored approach to the stakeholder involvement has been followed, in which different stakeholder groups are addressed in their specific needs and interests, rather than or prior to addressing them all together in the form of open joint sessions and workshops. The stakeholder involvement took place in (regular) face-to-face meetings, giving a good opportunity for intensive communication and the co-development of several tools and methods (see next sections).

The following table summarizes the stakeholder engagement:

Key Stakeholder	*Interest within PEARL*	*Way of engagement*
The Agency for Roads, Bridges and Waterways (LSBG)	Hazard and Risk assessment, developed modelling tools, early warning system	Regular face-to-face meetings on a monthly basis with key representatives
Ministry of Interior Affairs (BIS)	Evacuation model	Regular meetings including the assessment of need and interests
Hamburg Port Authority (HPA)	Hazard and risk assessment in the Hamburg Port area, early warning system	Regular face-to-face meetings with the key representatives
Federal Maritime and Hydrographic Agency (BSH)	Early warning system	Active involvement and exchange of experience, regular working meetings
Ministry of Environment and Energy (BUE, highest level of administrative body)	Final Results, Policy Briefs	Meetings with the officials
Agency for Coastal Protection, National Resources and Sea Protection Schleswig-Holstein (LKN-SH)	Hazard and risk assessment for the Schleswig-Holstein area, developed modelling tools	Occasional personalized meetings

In that sense, the approach that has been applied in the Elbe estuary case study can be understood as a further refinement of the general LAA concept.

AKTIVITÄT 1: Angepasste Beteiligung der Akteure

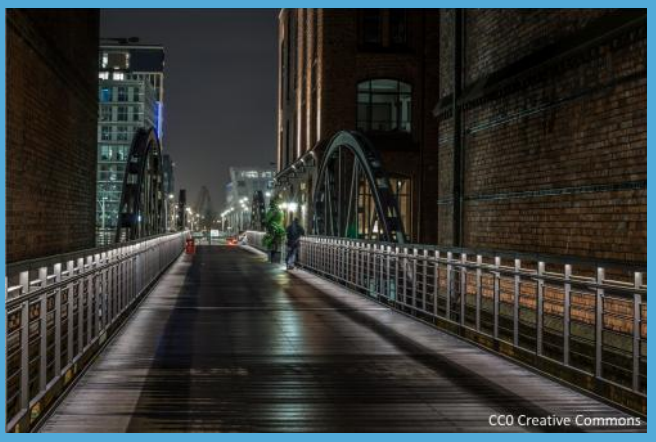
In der Vergangenheit trafen verschiedene schwere Sturmereignisse das Elbeästuar und die Stadt Hamburg (z.B. …, 1825, 1855, 1962, 1976). Im Laufe der schweren Sturmflut von 1962 traten entlang der Elbe zahlreiche Deichbrüche auf, die zu großflächigen Überflutungen des Hinterlandes führten. Infolge dieser Überschwemmungen verloren viele Menschen ihr Leben. Die immer wieder auftretenden Sturmfluten schufen ein ausgeprägtes Bewusstsein in der Bevölkerung und bei den Behörden für Sturmfluten und Hochwasser als erstzunehmende Gefahr und Risiko. Auf Seiten der Hochwasserschutzverantwortlichen führten diese Ereignisse zu einem Überdenken und einer Neugestaltung des Hochwasserschutzsystems entlang der Elbe.

Eine weitere Besonderheit besteht in der bereits erfolgten intensiven Einbeziehung der Akteure und Interessensvertreter in vorangegangenen Initiativen und Projekten (BMBF KLIMZUG-Nord, XtremRisk, Corfu). Die Erfahrungen aus diesen Projekten bilden den Ausgangspunkt für die Weiterentwicklung der LAAs. Es wurde eine Ansatz verfolgt, der weg von zeitaufwendigen Veranstaltungen mit einer Vielzahl von Akteuren hin zu einer auf die Bedürfnisse und Interessen spezifischer Akteure angepassten Beteiligung führte. Regelmäßige persönliche Treffen, welche die Möglichkeit zur intensiven Kommunikation und Diskussion bieten, haben sich hier als zielführend erwiesen. Die folgende Tabelle gibt hier einen Überblick:

Akteur	*Interessen in PEARL*	*Beteiligung*
Landesbetrieb Straßen, Brücken und Gewässer (LSBG)	Gefahren- und Risikobewertung, Entwicklung von Modellen, Frühwarnsystem	Monatliche persönliche Treffen
Behörde für Inneres und Sport (BIS)	Evakuierungsmodell	Regelmäßige Treffen
Hamburg Port Authority (HPA)	Gefahren- und Risikobewertung für den Hafen, Frühwarnsystem	Regelmäßige Treffen
Bundesamt für Seschifffahrt und Hydrographie (BSH)	Frühwarnsystem	Aktive Beteiligung und Erfahrungsaustausch, regelm. Arbeitstreffen
Behörde für Umwelt und Energie (BUE)	Endergebnisse, Policy Briefs	Treffen mit verschiedenen Vertretern
Landesbetrieb für Küstenschutz, Nationalpark und Meeresschutz Schleswig-Holstein (LKN-SH)	Gefahren- und Risikobewertung für Schleswig-Holstein, Entwicklung von Modellen	Gelegentliche persöniche Treffen

Die Gestaltung der LAAs als eine auf die Interessen und Bedürfnisse der Akteure zugeschnittene Beteiligung stellt eine Weiterentwicklung des übergeordneten Konzeptes für LAAs dar.

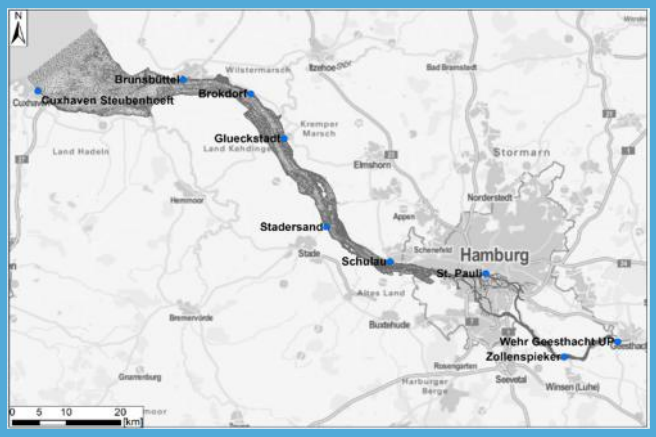
Flood protection dike and Speicherstadt / Hochwasserschutzdeich und Speicherstadt



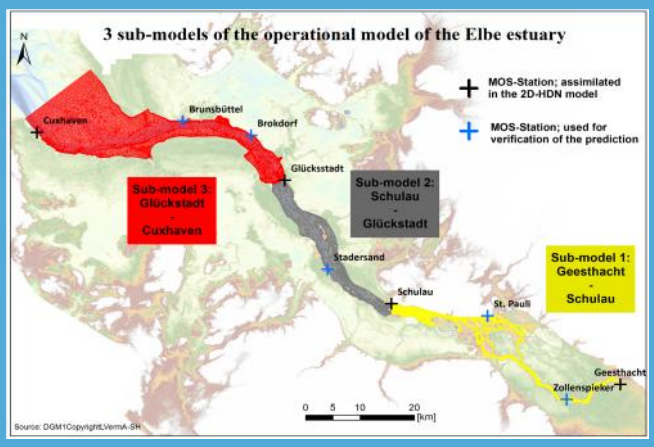
Pedestrian evacuation bridge in the Hafen City / Fußgängerevakuierungsbrücke in der Hafen City

Dwelling mound concept in the Hafen City / Hafen City mit Warftenkonzept

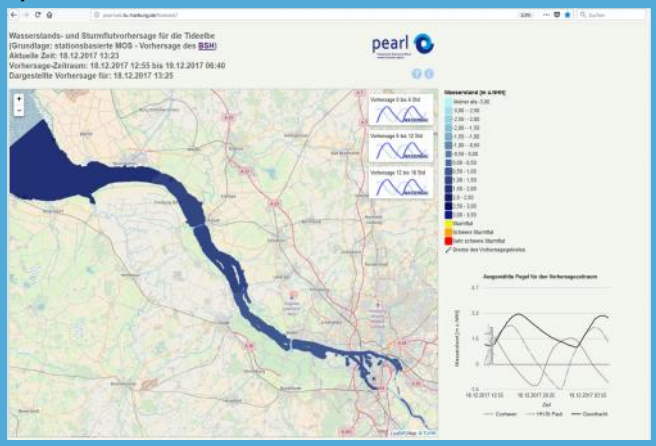
ACTIVITY 2: Early Warning System - Real-time Forecasting



BSH MOS stations / MOS-Stationen des BSH



Sub-models of the operational Elbe model / Teilmodelle des operationellen Elbemodells



Online-visualization of the forecast model / Onlinevisualisierung des Vorhersagemodells

In the scope of the PEARL project, a new and innovative modelling system for the real-time forecasting of water levels in the Elbe estuary has been developed and within a close collaboration with the Federal Maritime and Hydrographic Agency (BSH). The overall aim of this modelling system is to provide extended planar water level forecasts for the Elbe estuary and the city of Hamburg.

Pointwise water level forecasts of the BSH serve as a basis for the developed real-time forecasting system, on the one hand side. The BSH provides water level forecasts every 15 min for 9 MOS (**M**odel **O**utput **S**tatistic) stations along the Elbe estuary and a forecast period of up to six days on the basis of the BSH numerical model and statistical methods. Within the developed real-time forecasting system, the BSH water level forecasts are imported continuously from the external BSH server to an internal TUHH server. Within this process the data pre-processing is carried out and the reformatted data is stored in a local data base in the form of continuous time series.

On the other hand a 2D numerical hydrodynamic model of the project area is needed for the simulation of the water levels. The model domain covers the Elbe river section from the weir in Geesthacht at the Elbe kilometre 586 (upstream) to the mouth of the Elbe into the North Sea near Cuxhaven at Elbe kilometer 730. The hydrodynamic boundary conditions in the Elbe estuary and the numerical model, respectively, are characterized by the river discharge over the weir in Geesthacht, represented by measured discharge of the gauge Neu Darchau, and the incoming tidal wave from the North Sea, represented by measured water level at the gauge Cuxhaven. The calibrated hydrodynamic model of the Elbe estuary is the basis for the real-time simulation of planar water level forecasts.

In order to assimilate as much pointwise forecast data as possible, the hydrodynamic model has been divided into three sub-models. Each sub-model has two boundaries (upstream and downstream) located at a MOS location to assimilate and integrate the water level forecast into the sub-models. The sub-models are run in serial for a MOS water level forecast period. Each sub-model has at least MOS station in the middle of each sub-model for verification of the water level forecasts.

The results of the simulations are visualized in a free-available web-based access. Each forecast run represents water level for the next 18 hours. The forecast period and the current time are displayed in the header of the webpage and are updated after each forecast run. Water level heights are differentiated by a blue colour scale. If the water level reaches a critical level according to the storm surge definition of the Elbe estuary, water level will be coloured in yellow (storm surge), orange (heavy storm surge) or red (very heavy storm surge). Additionally, the water level hydrographs of selected gauges are permanently displayed on the web-page as reference hydrographs. Furthermore, by selecting a specific point in the Elbe estuary, water level popes up for the selected point at the selected time. Additionally, the portal provides the functionality of visualization of the water level of the selected point as a hydrograph or in a table as well as the download if the predicted water level (Shaikh et al. 2016). The water level forecast system is running and on-line (http://pearl.wb.tu-harburg.de/forecast/). It is already used by the BSH giving valuable input for the official early warning system of the BSH.

AKTIVITÄT 2: Frühwarnsystem - Echtzeitvorhersage

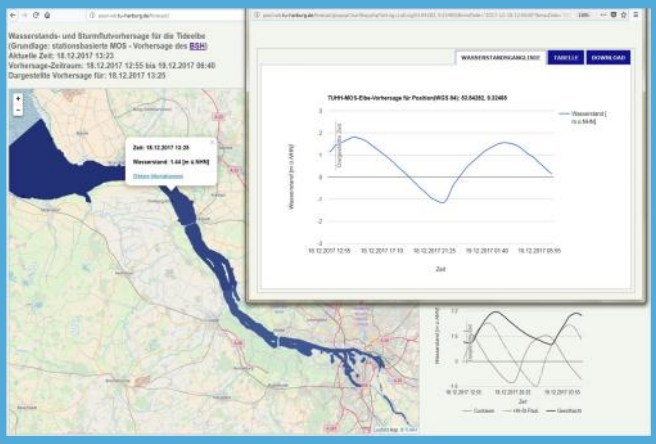
Im Rahmen des Projektes PEARL wurde in Zusammenarbeit mit dem BSH eine neues und innovatives Echtzeitvorhersagemodell für Wasserstände entlang der Elbe entwickelt, mit dem Ziel ein Echtzeitvorhersagemodell zur Verfügung zu stellen mit dessen Hilfe die punktuell verfügbaren Wasserstandsvorhersagen des BSH in flächige Wasserstandsvorhesagen transformiert werden können.

Das BSH stellt alle 15 min für 9 MOS (**M**odel **O**utput **S**tatistic) Stationen entlang der Elbe Wasserstandsvorhersagen für einen Vorhersagezeitraum von bis zu 6 Tagen zur Verfügung. Diese Wasserstandsdaten werden kontinuierlich von dem externen Server des BSH auf einen lokalen Server der TUHH heruntergeladen. Im Rahmen dieses Prozesses wird ebenfalls die Aufbereitung der Daten zur Verwendung in dem Vorhersagemodell durchgeführt. Die aufbereiteten Daten werden in Form von kontinuierlichen Zeitreihen in einer Datenbank gespeichert.

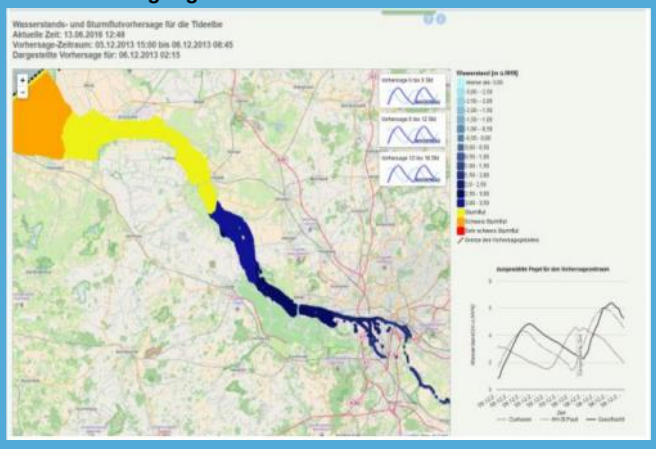
Andererseits wird ein 2D hydrodynamisch numerisches Modell zur Simulation der Wasserstände benötigt, das hier kurz beschrieben werden soll. Das numerische Modell bildet die Tideelbe zwischen dem Wehr in Geesthacht bei Elbekilometer 586 und der Elbemündung bei Elbekilometer 730 ab. Die hydrodynamischen Randbedingungen werden durch den Abfluss von oberstrom über das Wehr bei Geesthacht (Pegel Neu Darchau) kommend, einerseits, und der einlaufenden Tidewelle von der Nordsee kommend (Pegel Cuxhaven), andererseits, charakterisiert. Das kalibrierte hydrodynamisch numerische Modell der Elbe bildet die Basis für die flächige Simulation der Wasserstände. Um eine möglichst große Anzahl an Vorhersagedaten des BSH in das Modell einzubeziehen, wurde das numerische Modell in drei Teilmodelle, an dessen Rändern je eine MOS Station liegt, unterteilt. Die Teilmodelle werden seriell für einen Vorhersagezeitraum simuliert. Jedes Teilmodell enthält mindestens eine MOS Station zur Verifikation der Modellergebnisse.

Die Ergebnisse der Vorhersageläufe, der Vorhersagezeitraum beträgt 18 Stunden, werden auf einer frei-zugänglichen Webseite visualisiert (http://pearl.wb.tu-harburg.de/forecast/). Der Vorhersagezeitraum und der aktuelle Zeitschritt werden in der Kopfzeile angezeigt und nach jedem Vorhersagelauf aktualisiert. Die dargestellten Wasserstände können mit Hilfe einer Farbskala unterschieden werden. Hohe Wasserstände werden entsprechend der Einteilung der Sturmfluten für die Elbe in Gelb (Sturmflut), Orange (schwere Sturmflut) und Rot (sehr schwere Sturmflut) dargestellt. Zusätzlich sind die Wasserstandsganglinien ausgewählter Pegel permanent als Referenzpegel angezeigt. Durch Klicken auf einen beliebigen Punkt im Elbeästuar wird der dortige Wasserstand in einem neuen Fenster angezeigt. Weiterhin können für den ausgewählten Punkt die Ganglinie graphisch dargestellt werden sowie in tabellarischer Form heruntergeladen werden (Saikh et al. 2016).

Das Vorhersagemodell ist seit Mitte 2016 on-line und wird bereits vom BSH zur Unterstützung des offiziellen Frühwarnsystems genutzt.



Visualization of a water level hydrograph / Visualisierung einer Wasserstandsganglinie

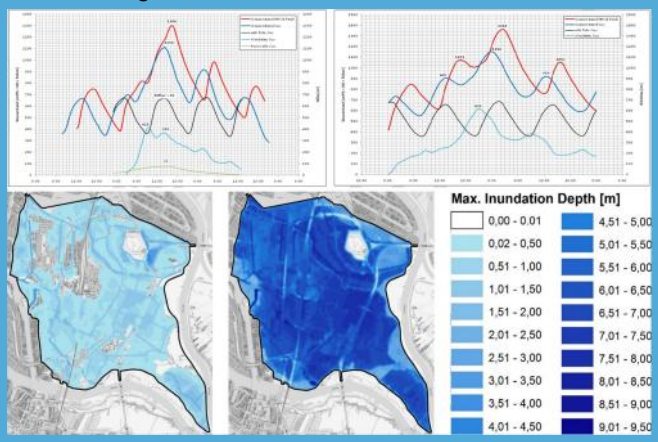


Visualization of a storm surge / Visualisierung einer Sturmflut

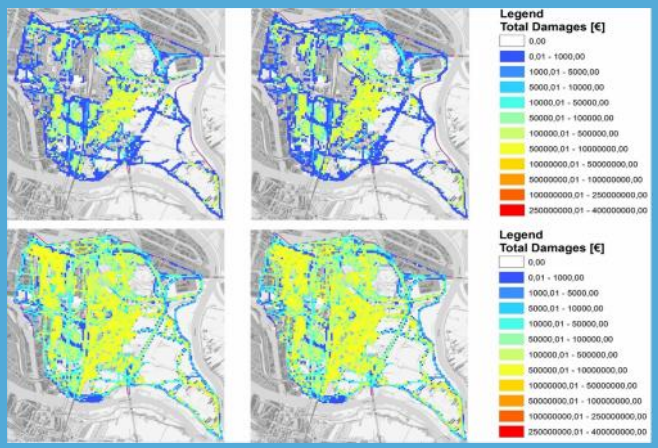
Visualization of the storm surge on Oct. 29th, 2017 / Visualisierung der Sturmflut am 29. Okt. 2017

ACTIVITY 3: Flood Risk Management & Evacuation

IBA 2013 projects in Wilhemsburg Central / IBA 2013 Projekte in Wilhelmsburg Mitte



Flood maps / Überflutungskarten



Flood damages: 2010 (left), 2017 (right) / Hochwasserschäden: 2010 (links), 2017 (rechts)

Cities and their districts are subjected to a constant development over the time; residential houses are built, commercial and industrial companies emerge and the infrastructure evolves in accordance to the urban development. Due to the constant urban development of residential, industrial and infrastructure areas, the rising flood risk develops over time accordingly. In the course of the project the temporal evolution of the flood risk of the build environment, including the industrial and infrastructure areas, of the island Wilhelmsburg has been assessed. In the course of a vulnerability assessment, the damage potentials (representing potential damages in monetary terms in dependency of the inundation depth) for the residential buildings, the commercial and industrial objects as well as the infrastructure (roads and railways) have been analysed. An investigation of the inundation propagation for different storm surge events within the hazard assessment led to the inundation depths, which have been used to calculate the flood damages. In combination with the return period of the storm surge events the associated flood risk can be calculated. The flood risk of the island of Wilhelmsburg has been calculated for two time horizons, being the year 2010 and the year 2016. These time horizons represent states of the urban development before and after the launching of the urban development project “Leap over the Elbe” and the International Building Exhibition in 2013 (IBA 2013). The results of the flood risk assessment show an increase of the flood risk in accordance to the urban development of the area. The results also vary within the different storm surge scenarios. The assessment of the temporal evolution of the flood risk can be useful tool to assess respectively re-assess existing flood management plans and strategies and to develop possible adaptation strategies if necessary.

Evacuation of residents from a flood prone area in case of failure of flood protection infrastructure represents a key activity in the scope of the emergency response and flood risk management. Hamburg University of Technology in collaboration with the Hamburg Ministry of Interior Affairs developed an evacuation model for the island of Wilhelmsburg on the basis of hybrid CPU/GPU computing. The overall evacuation concept encompasses pedestrian evacuation, evacuation by public transport and private cars, as well as the vertical evacuation. At present, the evacuation model covers the pedestrian evacuation to collecting points or to safe places as well as the evacuation of the people by public transport from the collecting points out of the area. The pedestrian evacuation is modelled using a mathematical-physical model, describing the movement of the pedestrians from their initial positions around their residential houses to the collecting points or refuges. The simulation of the pedestrian movement results in a distribution of the arrival times of the people at the collecting points. Once the pedestrians arrived at the collecting points they are further evacuated by public transport. The evacuation of the people by public transport is carried out using the open-source urban transportation model SUMO, in which the different bus routes, described in the evacuation concept for Wilhelmsburg, are implemented. It is possible to simulate different scenarios, in order to develop evacuation plans as part of the emergency responses.

AKTIVITÄT 3: Hochwasserrisikomanagement & Evakuierung

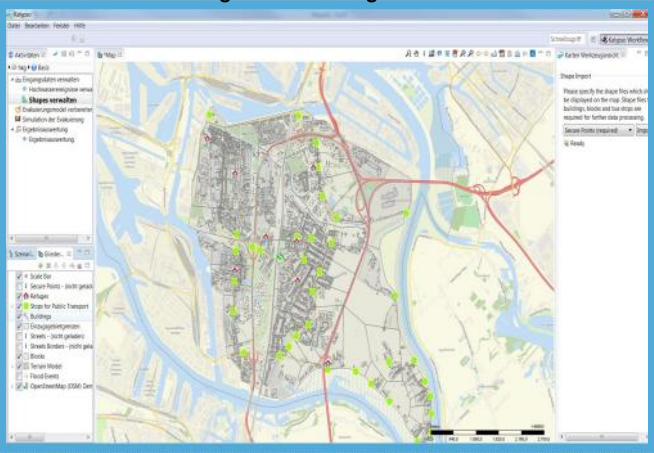
Urbane Gebiete sind einem Wandel unterworfen; Wohngebäude werden gebaut, Industrie- und Gewerbeunternehmen entstehen und die Infrastruktur in diesem Gebiet entwickelt sich. Aufgrund der steten Entwicklung der Städte mit ihren Wohn-, Gewerbe- und Industriegebieten sowie der Infrastruktur kommt es zu einer gleichzeitigen Entwicklung des Hochwasserrisikos.

Im Rahmen des Projektes wurde für Hamburger Stadtteil Wilhelmsburg die zeitliche Entwicklung des Hochwasserrisikos aufgrund der urbanen Entwicklung des Gebietes untersucht. In einer Vulnerabilitätsanalyse wurden die Schadenspotentiale für Wohngebäude, Industrie- und Gewerbeobjekte sowie für die Infrastruktur in monetärer Form analysiert und abgeschätzt. Eine Analyse des Ausbreitungsverhaltens von Überflutungen im Falle eines Versagens der Hochwasserschutzanlagen aufgrund verschiedener Sturmflutszenarien gab Auskunft über die zu erwartenden Überflutungswasserstände im Gebiet. Die Ergebnisse der Vulnerabilitätsuntersuchung und der Simulation der Überflutungsausbreitung wurden genutzt um die Hochwasserschäden zu berechnet. Eine Kombination der Hochwasserschäden mit den Eintrittswahrscheinlichkeiten der Sturmflutszenarien gibt Auskunft über das entsprechende Hochwasserrisiko. Die Berechnungen wurden für 2 unterschiedliche Zeithorizonte, die Jahre 2010 und 2016, vorgenommen. Die beiden Zeithorizonte stellen zwei unterschiedliche Zustände der Stadtentwicklung dar. Nämlich einen Zustand vor (2010) und nach dem (2016) dem Beginn des Stadtentwicklungsprogramms „Sprung über die Elbe“ bzw. der Internationalen Bauaustellung 2013 (IBA 2013). Die Ergebnisse der Berechnungen zeigten einen Anstieg des Hochwasserrisikos aufgrund der realisierten Bauprojekte auf dem Wilhelmsburger Stadtgebiet.

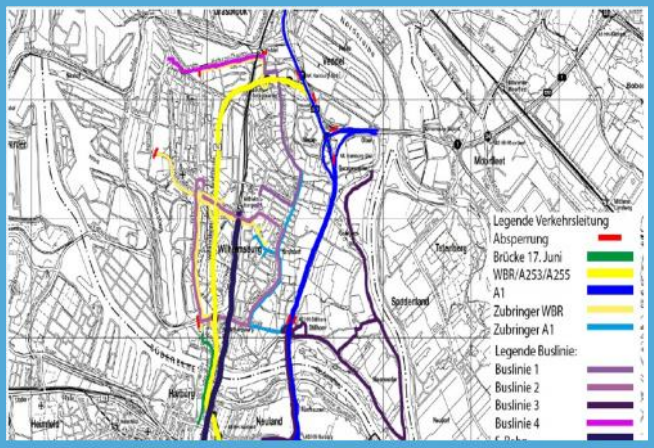
Die Analyse der zeitlichen Entwicklung des Hochwasserrisikos ist ein nützliches Werkzeug zur (erneuten) Überprüfung von existierenden Hochwasserrisikomangementplänen.

Die Evakuierung der Bevölkerung aus überflutungsgefährdeten Bereichen stellt eine Hauptaufgabe des Bevölkerungsschutzes und der Gefahrenabwehr im Falle einer Sturmflut dar. Die TUHH entwickelte in Zusammenarbeit mit der Behörde für Inneres und Sport ein Evakuierungsmodell für die Insel Wilhelmsburg auf der Grundlage hybriden GPU/CPU Computings. Das Evakuierungskonzept der Behörde beinhaltet die Evakuierung der Bevölkerung mit Hilfe öffentlicher und privater Verkehrsmittel, sowie die Evakuierung von Fußgängern und die vertikale Evakuierung. Zum jetzigen Zeitpunkt bildet das Evakuierungsmodell die Evakuierung von Fußgängern sowie die Evakuierung mit öffentlichen Verkehrsmitteln ab. Die Evakuierung von Fußgängern wird mit Hilfe eines mathematisch-physikalischen Modells, welches die Bewegung der Fußgänger von einem Ausgangspunkt hinzu einem Ziel (Sammelstellen oder Fluchtburgen) beschreibt, simuliert. Mit Hilfe dieses Modells können Aussagen über die Ankunftszeiten der Fußgänger an den Sammelstellen bzw. den Fluchtburgen getroffen werden. An die Evakuierung der Fußgänger anschließend kann die Evakuierung der Bevölkerung mit öffentlichen Verkehrsmitteln entlang ausgewählter, in dem Evakuierungskonzept der Stadt festgeschrieben, Routen simuliert werden. Die Simulation des Verkehrskonzeptes erfolgt mit dem open-source Modell SUMO (Sustainable Urban Mobility). Das entwickelte Evakuierungsmodell kann genutzt werden um existierenden Evakuierungspläne zu überprüfen, anzupassen oder zu entwickeln.

Storm surge information of Hamburg Wilhelmsburg / Sturmflut-Hinweise für Hamburg Wilhelmsburg

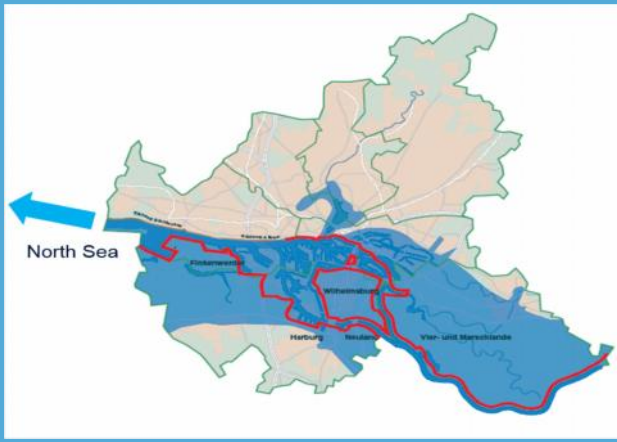


Visualization of the collecting point in the evacuation model / Visualisierung der Sammelpunkte im Evakuierungsmodell

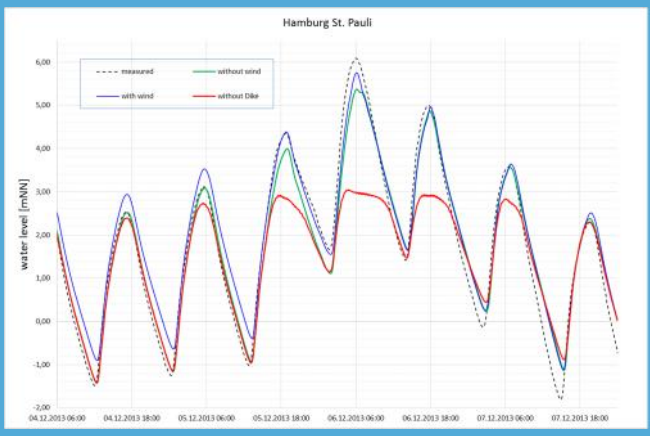


Evacuation routes for public and private transport / Evakuierungsrouten für öffentlichen und privaten Verkehr

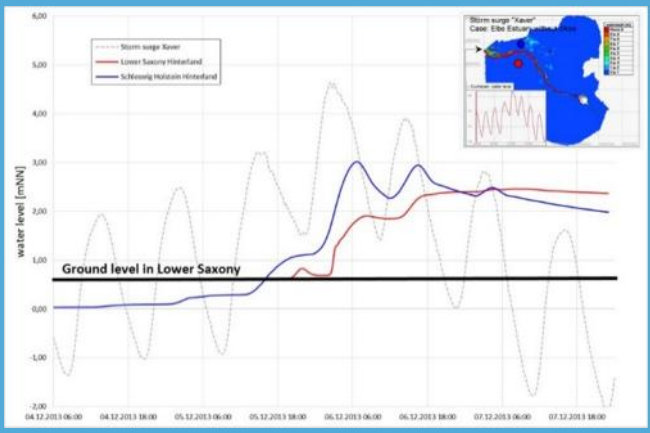
ACTIVITY 4: Analysis of Possible Adaptation Measures



Flood prone area / Überflutungsgefährdetes Gebiet



Water level hydrographs for historic and recent situation / Wasserstandszeitreihen für historische und aktuelle Situation



Comparison of ground levels (Lower Saxony), storm surge Xaver and water levels in the hinterland / Vergleich von Geländehöhen (Niedersachsen), Wasserstände der Sturmflut Xaver und Wasserständen im Hintelrhand

The Elbe Estuary and the City of Hamburg are protected by a continuous line of flood protection infrastructure along the river Elbe. All three federal states responsible for the Elbe Estuary (Hamburg, Schleswig Holstein and Lower Saxony) have high safety standards reflected in the design water level, which is derived in each federal state according to their own methods and statistics.

In Hamburg, the reinforcement and improvement of the existing flood protection line is performed within Construction Programs (Bauprogramme). Within the Program started 2007, the flood protection infrastructure is being elevated and reinforced in average for 1,0 m (LSBG, 2007) referring to the design water level at the St. Pauli gauging station of NN+7,30 m. Depending on their location and the considered loads (e.g. wind direction) the height of the infrastructure is between NN+ 7,60- NN+ 9,00 m. However, the reliability of the design parameters are continuously being checked, as due to climate change or changes in the land use, the current practices and flood protection strategies might be inappropriate for the future conditions.

In order to assess the hydrodynamic effects on the Low Elbe in case of storm surges, the present situation with the current flood protection infrastructure has been incorporated into the 2D HDN model of the Elbe estuary (see *Early warning – Real-time Forecasting*). Storm surges hydrographs derived on the basis of statistical approaches or measured storm surges hydrographs (e.g. Xaver in 2013) are used as hydrodynamic boundary conditions.

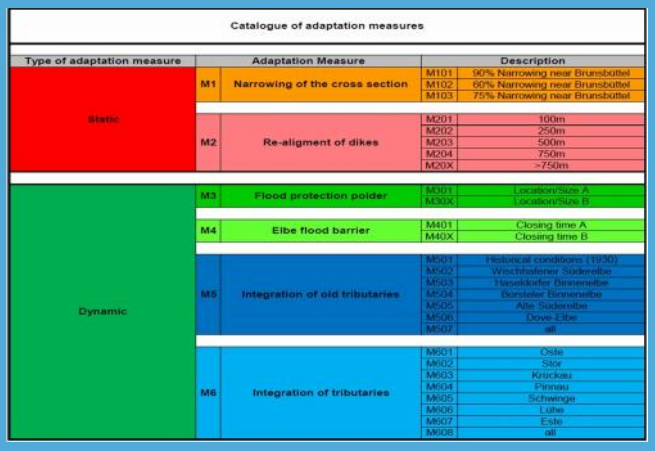
A preliminary assessment of the historic situation, without the continuous dike line along the Elbe estuary assuming the storm surge event “Xaver”, showed on the one hand, that the water level at the gauge Hamburg St. Pauli are significantly lower compared to the recent situation. On the other, the water levels along the Low Elbe during a storm surge event (e.g. Xaver) are higher than the average terrain elevation of the hinterland resulting in large inundated areas. These preliminary results illustrate advantages and disadvantages of the recent flood protection infrastructure along the Elbe estuary. Protection of low lying hinterland areas in Schleswig-Holstein and Lower Saxony against large scale inundations is beneficial. However, the high level flood protection infrastructure along the Elbe river leads to higher storm surge water levels in the Hamburg city area, due to missing space for the river in case of high water levels in the river. Witihn PEARL, the alternative or complementary measures and strategies, including the Nature Based Solutions (NBS) have been studies and their potential to mitigate the flood hazard and risk have been analysed. Re-alignment of the continuous dike line by 250 m and 500 m has been investigated. The preliminary results shows that a re-alignment of the dikes lead to a decrease of the water levels.

AKTIVITÄT 4: Analyse Möglicher Anpassungs-maßnahmen

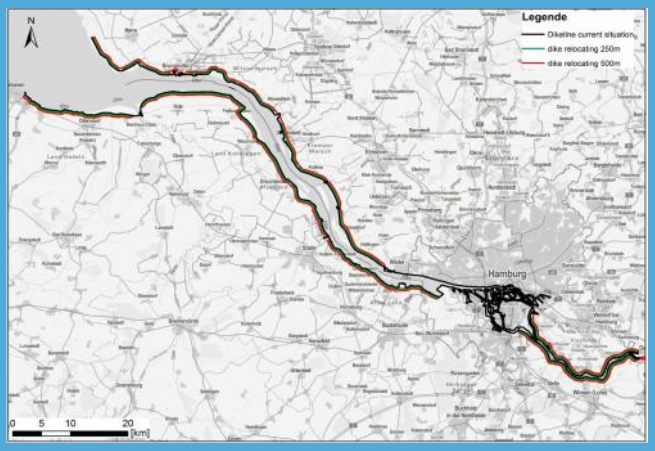
Das Elbeästuar und die Stadt Hamburg werden durch eine geschlossene Hochwasserschutzlinie gegen Sturmfluten und Hochwasser geschützt. Die drei Bundesländer (Schelswig-Holstein, Niedersachsen u. Hamburg) haben hohe Sicherheitsstandards, die sich in den Bemessungswasserständen der Hochwasserschutzanlagen widerspiegeln. Die Festlegung der Bemessungswasserstände erfolgt in den Bundesländern dabei anhand der geltenden Regelwerke.

In der Hansestadt Hamburg erfolgt die Verstärkung der existierenden Hochwasserschutzanlagen im Rahmen von Bauprogrammen. Im Jahr 2007 startete das letzte Bauprogramm in dem die Hochwasserschutzanlagen im Mittel um ca. 1,0m erhöht wurden. Der bis dahin geltende Bemessungwassertand betrug am Pegel Hamburg St. Pauli NN+7,30m. In Abhängigkeit der Lokation und den auftreten Belastungen betragen die Bauwerkshöhen zwischen NN + 7,6m und NN + 9,0m. Dennoch werden die Bemessungsparameter der Hochwasserschutzanlagen, auf Grund der sich ändernden Umweltbedingungen, regelmäßig überprüft und gegebenenfalls angepasst.

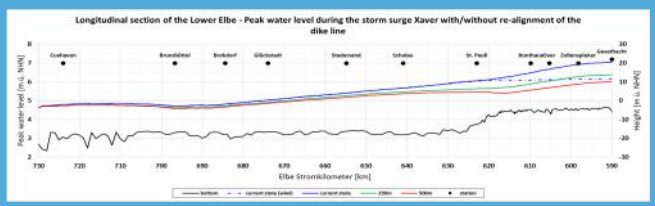
Um die hydrodynamischen Effekte von Sturmfluten auf das Elbeästuar bewerten zu können, wurde die existierenden Hochwasserschutzanalgen entlang der Elbe in das 2D hydrodynamisch numerischen Modells der Unterelbe implementiert. Statistisch abgeleitete oder aufgezeichnete Sturmflutganglinien werden als hydrodynamische Randbedingungen im Modell verwendet. Genauso kann der historische Zustand der Hochwasserschutzanlagen entlang der Elbe bewertet werden. Die Ergebnisse einer Simulation der Sturmflut „Xaver“ in Kombination mit einem historischen Zustand der Hochwasserschutzanlagen zeigten, dass die Wasserstände am Pegel Hamburg St. Pauli signifikant niedriger sind als mit dem gegenwärtigen Zustand der Hochwasserschutzanlagen. Zusätzlich zeigte sich, dass die Wasserstände in der Unterelbe während eines Sturmflutereignisses (z.B. Xaver) höher liegen als die mittleren Geländehöhen des Hinterlandes. Sollten die Hochwasserschutzanlagen versagen, würde es zu großflächigen Überschwemmungen kommen. Diese ersten Untersuchungsergebnisse illustrieren die Vor- und Nachteile des derzeitigen Hochwasserschutzsystems. Der Schutz der tiefliegenden Hinterlandgebiete in Niedersachsen und Schleswig-Holstein ist jedoch notwendig. Andererseits führen die Hochwasserschutzanlagen entlang der Elbe zu einer Einengung des Flusses, die sich in höher auflaufenden Sturmflutwasserständen manifestiert. Daher wurden im Rahmen des Projektes alternative und ergänzende Hochwasserschutzmaßnahmen, einschließlich naturnaher Maßnahmen (Nature Based Solutions) untersucht und ihr Potential in Bezug auf die Hochwasserminderung. In ersten Untersuchungen wurden verschiedene Szenarien der Deichrückverlegung, um 250m und 500m, untersucht. Erste vorläufige Ergebnisse zeigen, dass eine Deichrückverlegung zu einer Verringerung der Wasserstände in der Elbe im Sturmflutfall führt.



Adaptation measures / Anpassungsmaßnahmen

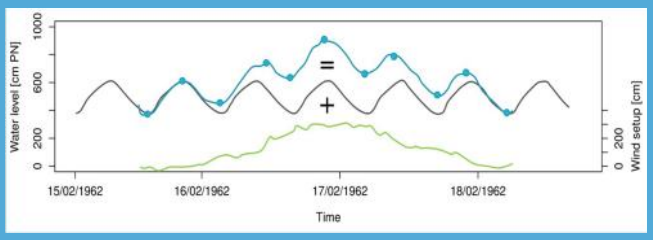


Dike re-alignment scenarios / Deichrückverlegungsszenarien

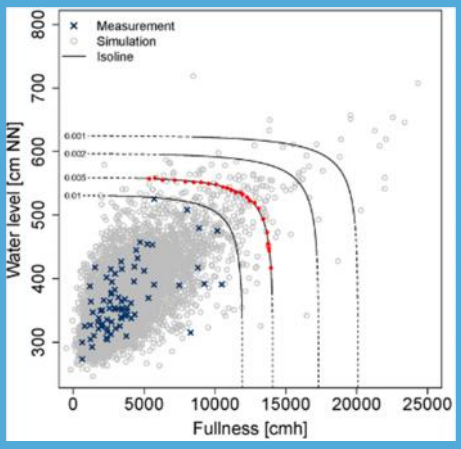


Effects of the dike re-alignment on the water level / Auswirkungen der Deichrückverlegungs auf den Wasserstand

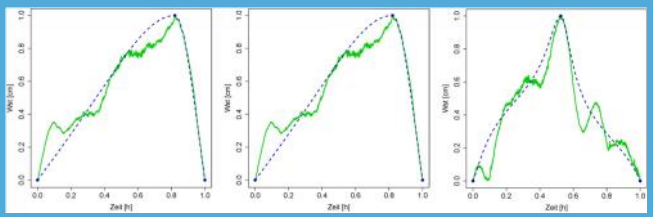
ACTIVITY 5: Hazard Assessment & Storm Surge Generator



Superposition of astronomical tide and wind set-up / Überlagerung von astronomischer Tide und Windstau



Events with identic return period / Ereignisse mit gleichem Wiederkehrintervall



Standadisation of measured storm surge hydrographs / Standardisierung gemessener Sturmflutganglinien

Storm surges in an estuarine area can be regarded as a superposition of the regular astronomical tide and an increased wind set-up. In order to characterize these extreme hydrometeorological events, statistical analyses have been performed. Due to the interdependency of the parameters which characterize a storm surge, multivariate statistical approaches need to be applied. In the following the approach for the multivariate statistical analysis is briefly described. The distribution function of a bivariate sample can be derived by means of the marginal distribution function of the univariate samples and a copula function describing the dependence structure of the both random variables. The marginal distribution of the univariate samples can be derived using methods of the extreme value statistics. The aim of the bivariate statistical analysis is the identification of the copula function describing the bivariate sample best. There are different copula functions available describing the correlation of the random variables, which can be tested in order to identify the best fitting copula function. For each copula functions corresponding so called generator functions exist. A probability of occurrence can be assigned to an arbitrary number of combinations of random variables (u,v) in an interval between (0,1). The goodness of fit is assessed by comparing combinations of measured parameters (e.g. water level and sea state, water level and fullness) and simulated combinations. Thereto, an arbitrary number of equally distributed random variables in the interval (0,1) is created. Inserting the equally distributed random variables in the reverse function of the derivation of the copula function lead to interdependent random variables (u,v).

These random variable (u,v) are inserted into the reverse function of the univeriate marginal distribution functions and the simulated pairs of data are converted into real units (Genest and Favre 2007; Salecker et.al. 2012, Fröhle et.al. 2014).

By the means of this methodology an arbitrary number of combinations of water level and fullness with a conjoint identic probability of occurrence can be derived which can further be used to derive storm surge hydrographs. Basis for the creation of new storm surge hydrographs are standardized courses of the wind set-up of measured storm surge hydrographs. The standardized hydrograph can be divided into an ascending (left part) and descending part (right part). The course of the left and right of the peak water level is simulated separately (Salecker et.al. 2012, Fröhle et.al. 2014) and both simulated and standardized courses of the wind set-up are scaled using the previous derived water level and fullness (Salecker et.al. 2012, Fröhle et.al 2014). By adding the mean tide to the scaled wind set-up new storm surge hydrographs are created.

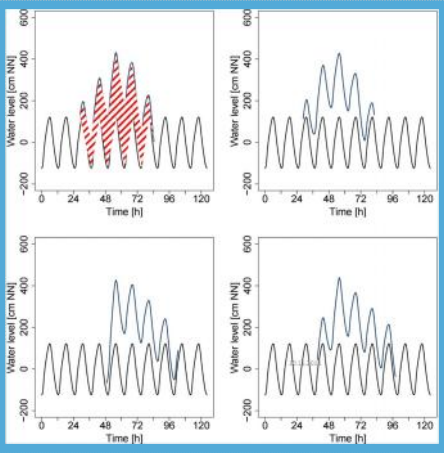
The described approach is implemented into a storm surge generator. Using the storm surge generator a large number of storm surge hydrographs can be generated automatically. There are two options for generating storm surge hydrographs. The user can define the return period and the desired number of storm surges for a specific gauge location. The second option is to define a specific period of time for which the storm surge hydrographs are generated (Fröhle et.al. 2014).

Aktivität 5: Gefahrenanalyse & Sturmflutgenerator

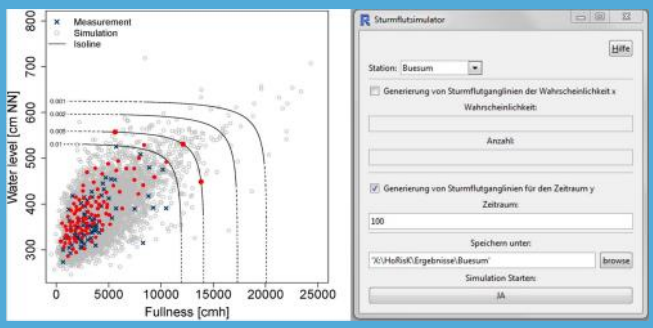
Sturmfluten in tidebeeinflussten Gebieten und Ästuaren, können als eine Überlagerung von astronomischer Tide und erhöhten Windstau betrachtet werden. Um diese Extremereignisse charakterisieren, wurden statistische Untersuchungen auf der Grundlage bivariater statistischer Analyse durchgeführt. Die Verteilungsfunktion einer bivariaten Stichprobe kann mit Hilfe der Randverteilungsfunktionen der univariaten Stichproben und einer Copulafunktion, welche die Abhängigkeitsstruktur der unabhängigen Variablen beschreibt, bestimmt werden. Die Randverteilungsfunktionen der unabhängigen Variablen können mit den Methoden der univariaten Extremwertstatistik bestimmt werden. Das Ziel der bivariaten statistischen Analyse ist die Identifizierung der Copulafunktion, welche die bivariate Stichprobe am besten beschreibt. Es stehen hier die verschiedensten Copulafunktionen zur Verfügung, welche auf ihre Eignung überprüft werden können. Jeder Copulafunktion ist eine Generatorfunktion zugeordnet. Im Zuge der bivariaten statistischen Analyse können der Stichprobe (u,v) Eintrittswahrscheinlichkeiten im Intervall von (0,1) zugeordnet werden. Die Anpassungsgüte der gewählten Copulafunktionen erfolgt anhand des Vergleichs der Kombination gemessener Parameter (z.B. Wasserstände und Seegang, Wasserstand und Fülle) und den entsprechenden simulierten Kombinationen. Hierzu wird eine beliebige Anzahl von gleichverteilten zufälligen Variablen im Intervall (0,1) generiert. Werden diese Variablen in die Umkehrfunktion der Ableitung der Copulafunktion eingesetzt, können die unabhängigen zufälligen Variablen (u,v) abgeleitet werden. Mit Hilfe der Umkehrfunktionen der Randverteilungsfunktionen aus dem univariaten Fall, können den zufälligen Variablen (u,v) in reale Einheiten transformiert werden (Genest and Favre 2007, Salecker et al. 2012, Fröhle 2014).

Mit Hilfe dieser Methodik kann eine beliebige Anzahl von Kombinationen von Wasserstand und Fülle mit identischer Eintrittswahrscheinlichkeit abgeleitet werden, die als Eingangsgrößen für die Generierung von Sturmflutganglinien dienen können. Grundlage für die Generierung neuer Sturmflutganglinien bilden standardisierte Windstauverläufe gemessener Sturmflutganglinien. Diese standardisierten Verläufe könne in einen aufsteigenden (linker Ast) und einen absteigenden Ast (rechter Ast) unterteilt werden. Die Verläufe der einzelnen Windstauäste werden separat simuliert (Salecker et al. 2012, Fröhle 2014) und mit Hilfe der zuvor abgeleiteten Wasserständen und Füllen skaliert. Die neuen Sturmflutverläufe werden durch Hinzufügen der astronomischen Tide kreiert.

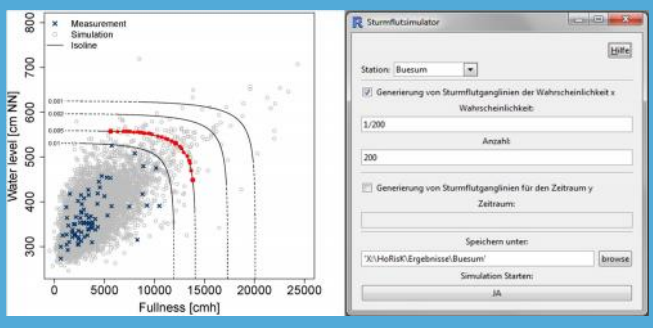
Dieser Methodik wurde in einen Sturmflutgenerator implemtiert, mit dessen Hilfeeine Vielzahl von Sturmflutganglinien automatisch generiert werden können. Es stehen zwei Funktionalitäten zur Verfügung. Einerseits können Ganglinien für ein definiertes Wiederkehrintervall in einer gewünschten Anzahl für eine beliebige Lokation generiert werden. Andererseits, können für einen beliebigen Zeitraum Sturmfluten mit verschiedenen möglichen Wiederkerhintervallen generiert werden.



Different events with identic return period / Unterschiedliche Ereignisse mit gleichem Wiederkehrintervall



Events in a period of time / Ereignisse für einen bestimmten Zeitraum



Events with identic return period / Ereignisse mit gleichem Wiederkehrintervall

LESSONS LEARNED, RESULTS & DISCUSSION

Hamburg sea port evening ambience / Hamburger Hafen Abendstimmung

Reloading points evening ambience / Umschlagplätze Abendstimmung

Speicherstadt evening ambience / Speicherstadt Abendstimmung

Strong winds and storms over the North Sea causing storm surges and extreme water levels propagating upstream the Elbe river pose serious threads to the Elbe estuary and the cities located along the estuary. The devastating storm surge event in 1962 gave the authorities and the public a reality check. The awareness for extreme hydro-meteorological events and their adverse impact rose and responsible stakeholders (authorities) and the public have been sensitized over the years. Intensive engagement of the stakeholders in previous initiatives and participatory planning actions undertaken in several national and international projects (BMBF KLIMZUG-Nord and XtremRisK projects or FP7 Project CORFU) related to climate change and flood took place over the years, which has, as a consequence, higher awareness for the relevance of the issue. At the same time fatigue towards such stakeholder engagement activities arrived. Therefore, engagement of the key stakeholder must be tailored to their specific needs and interest, resulting in an adjusted LAA approach, being the (regular) face-to-face meetings.

The bilateral stakeholder meetings provide the opportunity of intensive communication and fruitful discussions to directly address the needs and interest of the relevant key stakeholder. On the basis of such a bilateral stakeholder engagement, for example, it was possible to develop the water level forecast system of the Lower Elbe, which is already used by the BSH to support their early warning system.

The experience of the public, stakeholder and authorities with the extreme storm surges in the past, strengthened the awareness of the public and the authorities of storm surges as a potential thread. Flood protection infrastructure and flood risk management plans have been developed and enhanced accordingly, by the authorities responsible for flood protection, providing nowadays a high safety level. But nevertheless, there is the awareness of flood protection as a permanent task.

Erkenntnisse & Diskussion

Starkwinde und Stürme über der Nordsee, die Sturmfluten verursachen, welche die Elbe nach oberstrom laufen, stellen für die Hinterland entlang der Elbe und Hamburg eine ernstzunehmende Gefahr dar. Die verheerende Sturmflut von 1962 öffnete der Bevölkerung und den Behörden die Augen und festigte das Bewusstsein für Sturmfluten als einer Gefahr, welche man nicht zu unterschätzen hat.

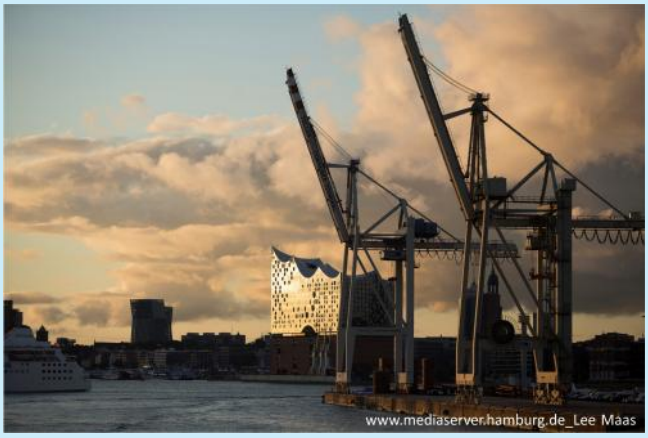
Durch die intensive Beteiligung der Behörden und Interessenvertretern in verschiedenen Initiativen und partizipative Planungsaufgaben im Rahmen vorangegangener nationaler und internationaler Projekten zu dem Themen Klimawandel und Hochwasser (BMBF KLIMZUG-Nord, XtremRisK projects, FP7 Project CORFU), entwickelten dieses eine stärkere Wahrnehmung für die Problemstellung. Gleichzeitig zeigten sich eine gewisse Ermüdungserscheinung und eine Abneigung bei den Interessensvertretern an weiteren solchen Aktivitäten teilzunehmen. Daher war es notwendig die Art und Weise in der Interessensvertreter und Behörden in Projekten beteiligt werden, auf die speziellen Interessen und Bedürfnisse der jeweiligen Institution anzupassen. Regelmäßige persönliche Treffen haben sich hier als zielführend erwiesen.

Bilaterale Treffen bieten die Möglichkeit der intensiven Kommunikation und Diskussion. So war es möglich in Zusammenarbeit mit dem BSH ein Wasserstandsvorhersagemodell für die Elbe entwickeln, welches flächige Vorhersagen des Wasserstandes auf Grundlage der punktuellen BSH-Vorhersagen liefert.

Die Erfahrung der Bevölkerung, Interessensvertretern und der Behörden mit den extremen Sturmfluten der Vergangenheit, verfestigten die Wahrnehmung, dass Sturmfluten eine Gefahr für Leib und Leben darstellen gegen die man sich schützen muss. Entsprechende Hochwasserschutzanalgen und Hochwasserrisikomanamentpläne sind entwickelt und über die Jahre verstärkt und verbessert worden, so dass diese heute auf einem hohen Sicherheitsstandard sind. Nichtsdestotrotz sind sich alle Behörden und Verantwortlichen bewusst, dass Hochwasserschutz eine Daueraufgabe ist.

Hamburg sea port evening ambience / Hamburger Hafen Abendstimmung

Port cranes / Hafenkräne



Port cranes and Elbphilharmony / Hafenkräne und Elbphilharmonie

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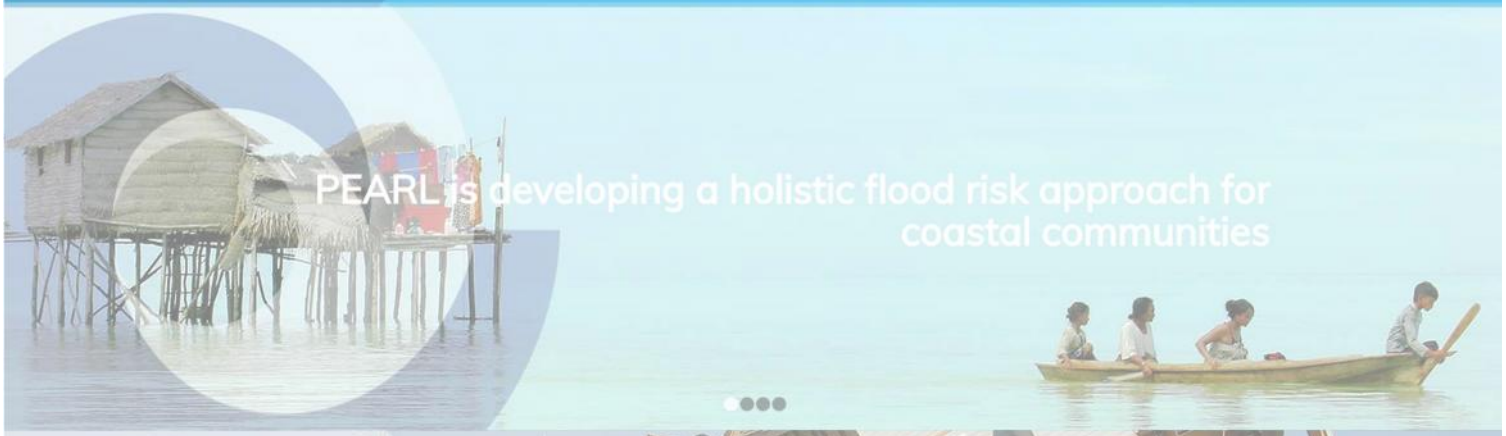
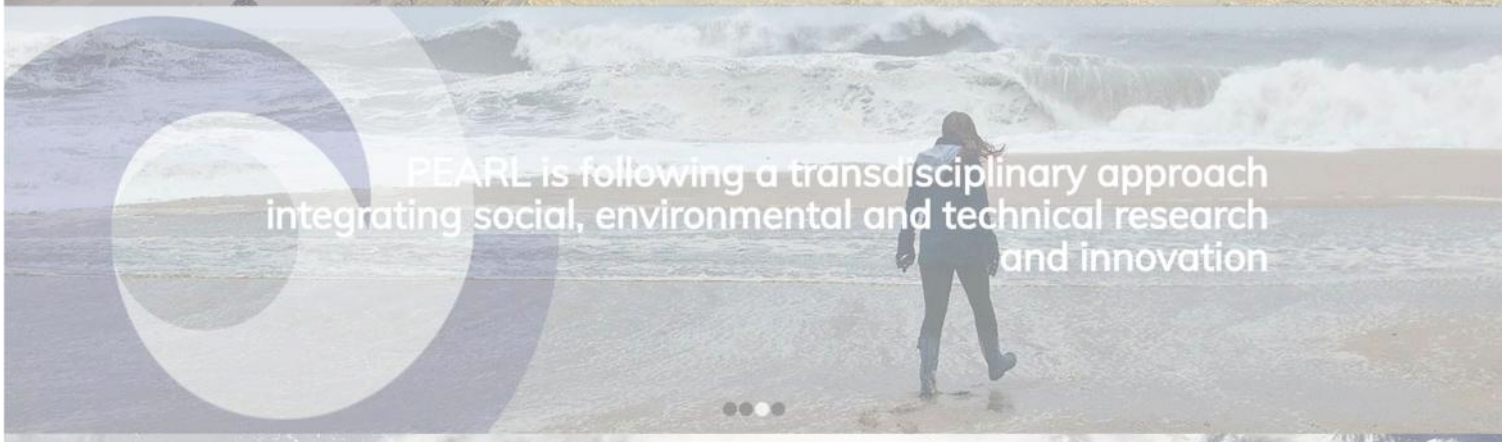
Preparing for Extreme And Rare events in coastaL regions

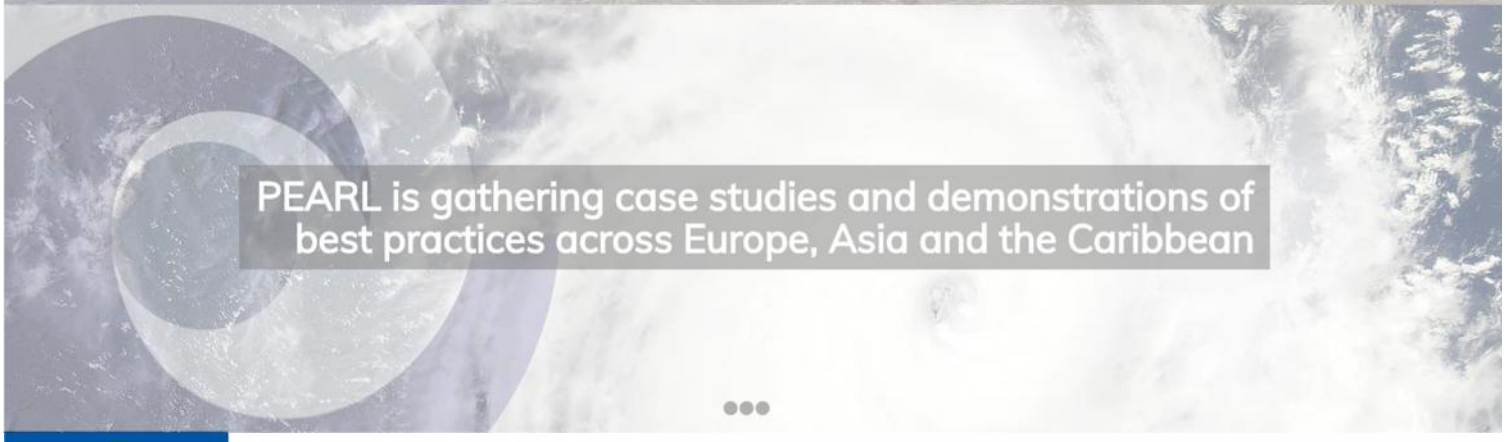


PEARL is developing a holistic flood risk approach for coastal communities

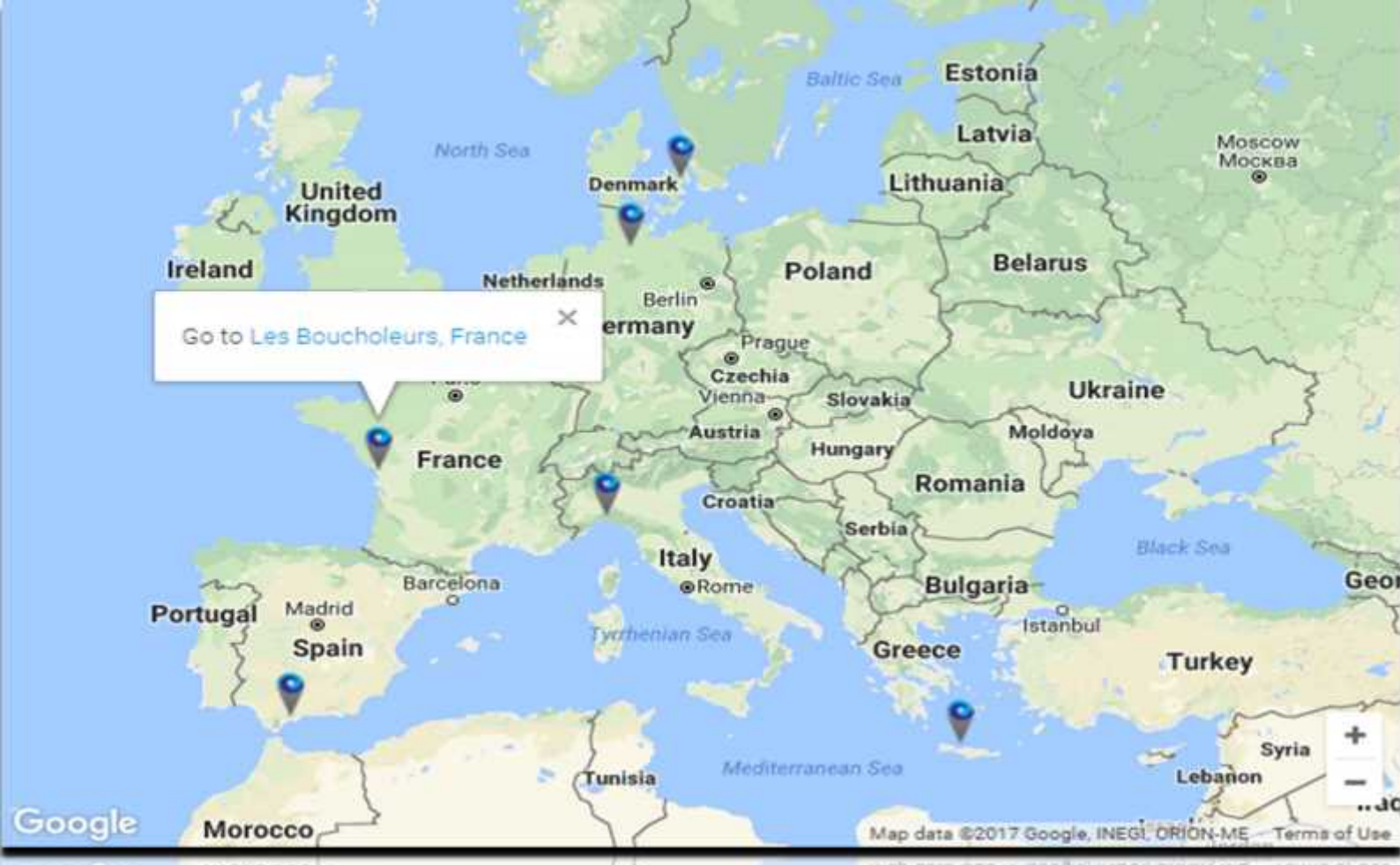
PEARL is improving forecasting, prediction and early warning capabilities



PEARL is following a transdisciplinary approach integrating social, environmental and technical research and innovation



PEARL is gathering case studies and demonstrations of best practices across Europe, Asia and the Caribbean



Risk Management Roadmap for the case study of Les Boucholeurs, France

University Nice Sophia Antipolis
Université de Nice-Sophia Antipolis

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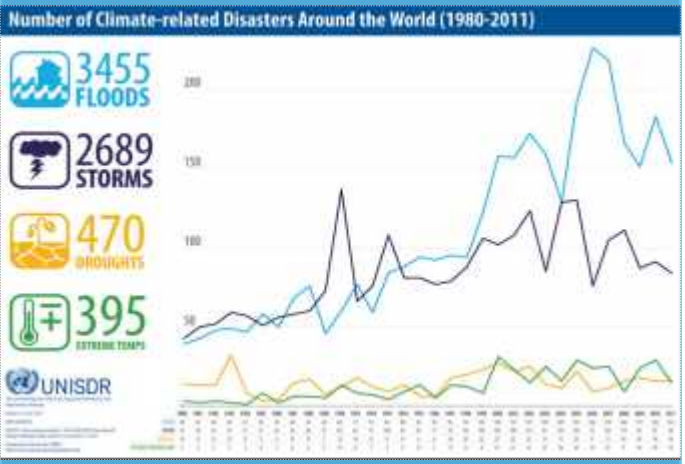
Preparing for Extreme And Rare events in coastal regions

FLOOD RISK & FLOOD RISK MANAGEMENT

Flooding & Impact/ Inondation et impact



Statistics / Statistiques

Flood Types / Types d'inondation

Coastal floods are regarded as one of the most dangerous and harmful of all natural disasters. Rapid urbanisation in coastal areas combined with climate change and poor governance can lead to a significant increase in the risk of local pluvial flooding coinciding with high water levels in rivers and high tide or storm surges from the sea, posing a greater risk of devastation in coastal communities.

There is a need to improve forecasting, prediction and early warning capabilities using state of art science and technology to help policy makers and emergency services to develop robust risk reduction strategies. However, forecasting and prediction is only part of the answer. Of equal importance is the ability to effectively warn the population in areas that will be affected, and that warning systems for the general public are integrated into broader management strategies and supported by appropriate institutional and organisational arrangements. Preparing for effective response to extreme events not only involves technology but also significantly social, economic, organisational and political considerations.

Flood risk management aims to reduce the likelihood and/or the impact of floods. Experience has shown that the most effective approach is through the development of flood risk management programmes incorporating the elements of prevention, protections, preparedness, emergency response, recovery and lessons learned. Reducing human casualties and damage to economic activity and the environment are key objectives shared by all EU countries and implementation of the 2007 Floods Directive has an important role in making this happen.

The Directive applies to all kinds of floods (river, lakes, flash floods, urban floods, coastal floods, including storm surges and tsunamis) and it is being implemented in a three-base process i.e. the preliminary flood risk assessment, the development of floods hazard and flood risk maps and eventually the production of flood risk management plans. River Basin Districts are the main units for the management of river basins, as described within the Water Framework Directive, therefore, they were adopted for the EU Flood Directive too.

Flood maps are being used by many different stakeholders within flood risk management and serve purposes related to prevention of the build-up of new risk, reduction of existing ones and adaptation to changing risk factors. Development and use of flood maps serves multiple purposes such as conduction of flood risk management plans, land use planning and land management, emergency planning, public awareness raising and within the private sector e.g. insurance assessment and pricing.

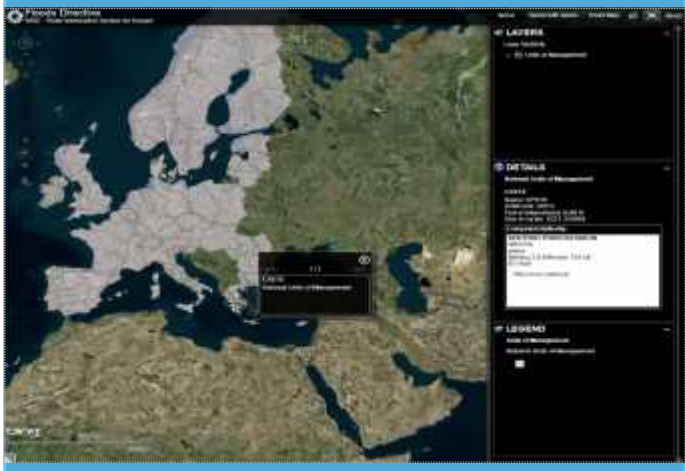
Floods, among others, are commonly referred to as natural disasters but they are not in fact the results of nature-related processes alone. They are to an ever-increasing extent directly attributable to various social, economic, historical, political and even cultural issues. The perception of flood impact on life and daily activities can be significantly different amongst the population and the level of knowledge and understanding of flood risk in a given area is directly related to people's decisions to either adjust their living to such a risk or simply to ignore it.

The PEARL project sought to fill in the lack of interaction between social aspects and technical measures – appearing to be a major hindrance for solving some of the greatest problems associated with floods and flood-related disasters.

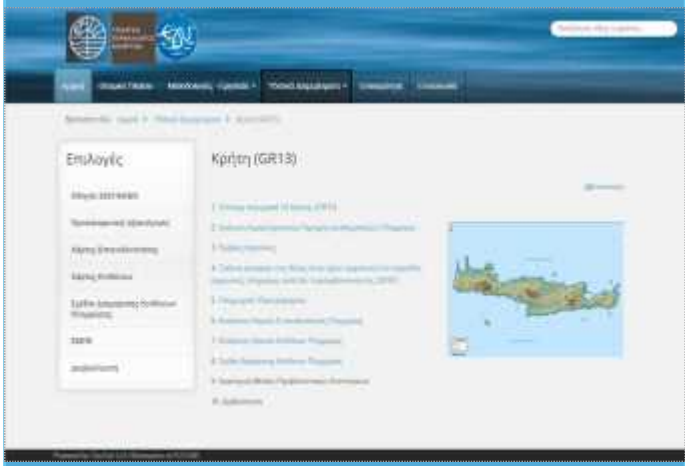
http://www.pearl-fp7.eu/

RISQUE D'INONDATION ET GESTION DES RISQUES D'INONDATION

Les inondations côtières sont considérées comme l'une des catastrophes naturelles les plus dangereuses et les plus dangereuses. L'urbanisation rapide dans les zones côtières combinée au changement climatique et à la mauvaise gouvernance peut entraîner une augmentation significative du risque d'inondation pluviale locale coïncidant avec des niveaux d'eau élevés dans les rivières et marées hautes ou ondes de tempête, ce qui augmente le risque de dévastation côtière. communautés. Il est nécessaire d'améliorer les capacités de prévision, de prédiction et d'alerte précoce en utilisant la science et la technologie de pointe pour aider les décideurs et les services d'urgence à élaborer de solides stratégies de réduction des risques. Cependant, la prévision et la prédiction ne sont qu'une partie de la réponse. La capacité d'avertir efficacement la population dans les zones qui seront touchées est tout aussi importante, et les systèmes d'alerte destinés au grand public sont intégrés dans des stratégies de gestion plus larges et soutenus par des arrangements institutionnels et organisationnels appropriés. Se préparer à une réponse efficace aux événements extrêmes implique non seulement une technologie mais aussi des considérations sociales, économiques, organisationnelles et politiques significatives. La gestion des risques d'inondation vise à réduire la probabilité et / ou l'impact des inondations. L'expérience a montré que l'approche la plus efficace consiste à élaborer des programmes de gestion des risques d'inondation intégrant les éléments de prévention, de protection, de préparation, d'intervention d'urgence, de rétablissement et de leçons apprises. La réduction des pertes humaines et des dommages à l'activité économique et à l'environnement sont des objectifs clés partagés par tous les pays de l'UE et la mise en œuvre de la directive de 2007 sur les inondations a un rôle important à jouer dans ce sens.La directive s'applique à tous les types d'inondations (rivières, lacs, crues soudaines, inondations urbaines, inondations côtières, y compris les ondes de tempête et les tsunamis) et est mise en œuvre dans un processus en trois étapes: évaluation préliminaire des risques d'inondation, développement des inondations des cartes des risques et des risques d'inondation et, éventuellement, la production de plans de gestion des risques d'inondation. Les districts hydrographiques sont les principales unités de gestion des bassins fluviaux, tels que décrits dans la directive-cadre sur l'eau. Ils ont donc également été adoptés pour la directive européenne sur les inondations. Les cartes des inondations sont utilisées par de nombreux intervenants dans la gestion des risques d'inondation et servent à prévenir l'accumulation de nouveaux risques, la réduction des risques existants et l'adaptation aux facteurs de risque changeants. Le développement et l'utilisation des cartes d'inondation servent à plusieurs fins telles que la conduite des plans de gestion des risques d'inondation, l'aménagement du territoire et la gestion des terres, la planification d'urgence, la sensibilisation du public et dans le secteur privé, évaluation d'assurance et tarification. Les inondations, entre autres, sont communément appelées catastrophes naturelles, mais elles ne sont pas, en réalité, uniquement le résultat de processus liés à la nature. Elles sont de plus en plus directement attribuables à divers facteurs sociaux, économiques, historiques, politiques et même La perception de l'impact de la nourriture sur la vie et les activités quotidiennes peut être significativement différente au sein de la population et le niveau de connaissance et de compréhension du risque d'inondation dans une zone donnée est directement lié aux décisions des individus d'adapter leur vie à un tel risque simplement pour l'ignorer. Le projet PEARL a cherché à combler le manque d'interaction entre les aspects sociaux et les mesures techniques - ce qui semble être un obstacle majeur pour résoudre certains des plus grands problèmes associés aux inondations et aux catastrophes liées aux inondations.



Flood Directive / Directive sur les inondations



Implementation / Implémentation

Management/ Lagestion

THE PEARL PROJECT: Methods & Tools

PEARL Project / Projet PEARL

Case Studies / Études de cas

Partners / Les partenaires

The PEARL project, a collaborative research project with 4year duration, worked towards the development ofadaptive, sociotechnical risk management measures and strategies for coastal communities against extreme hydro-meteorological events minimising social, economic and environmental impacts and increasing the resilience of Coastal Regions in Europe. PEARL received funding from the European Union's Seventh Framework Programme for Research, Technological Development and Demonstration (EU-FP7) under the theme "Coasts at threat in Europe: tsunamis and climate-related risks" (ENV.2013.6.4-3).

The PEARL consortium consisted of 24 partners from 13 countries from Europe and Asia, with significant experiences of severe flood risk in coastal regions and advanced flood early warning systems. Project's leader was the UNESCO-IHE.

The project examined 6 case studies from across Europe and 5 pilots from the Caribbean and Asia. Those were:

- Greve, Denmark
- Elbe Estuary, Germany
- Les Boucholeurs, France
- Genoa, Italy
- Marbella, Spain
- Rethymno, Crete, Greece
- St. Maarten
- St. Lucia
- Tohoku, Japan
- Taiwan
- Ayutthaya, Thailand

The research activities which were conducted within the project provided a plethora of products i.e. methodological frameworks, tools and applications, as well as policy briefs and publications. The most indicative ones were:

- Risk and Root Cause Assessment framework
- Vulnerability assessment framework
- Innovative hazard assessment and modelling concepts for individual or combined extreme events and several scales
- Frameworks for impact/damages (direct/indirect, tangible/intangible), economic and public health impact assessment due to multiple causes and scenarios
- Toolkit for holistic/multiple risk and impact/damage assessment at strategic and operational levels
- Operational Early Warning Systems and new methodologies for their effective dissemination
- Novel methodologies and concepts for achieving faster simulations and for uncertainty propagation analysis
- Frameworks for stakeholders' analysis and engagement i.e. the Learning and Action Alliances
- Frameworks and tools for flood resilience assessment of urban systems
- Intelligent knowledge base for resilience measures and strategies and tools/algorithms supporting their selection
- Interactive web-based learning and planning platform
- Risk Management Roadmaps specifically tailored to case study needs
- Information system infrastructure for data and meta data management

All outcomes/products and their integration formed the holistic approach and eventually the PEARL holistic framework enhancing prevention, mitigation and preparedness capabilities and building flood resilience of coastal urban systems.

L'INITIATIVE PEARL

http://www.pearl-fp7.eu/

Le projet PEARL, projet de recherche collaboratif de quatre ans, a travaillé au développement de mesures et stratégies de gestion des risques socio-techniques pour les communautés côtières contre les événements hydrométéorologiques extrêmes minimisant les impacts sociaux, économiques et environnementaux et augmentant la résilience des régions côtières en Europe. PEARL a reçu des fonds du septième programme-cadre de recherche, de développement technologique et de démonstration de l'Union européenne (UE-FP7) sous le thème «Les côtes menacées en Europe: tsunamis et risques liés au climat» (ENV.2013.6.4-3).

Le consortium PEARL était composé de 24 partenaires de 13 pays d'Europe et d'Asie, avec des expériences significatives de risques d'inondation sévères dans les régions côtières et des systèmes avancés d'alerte avancée en cas d'inondation. Le chef du projet était l'UNESCO-IHE.

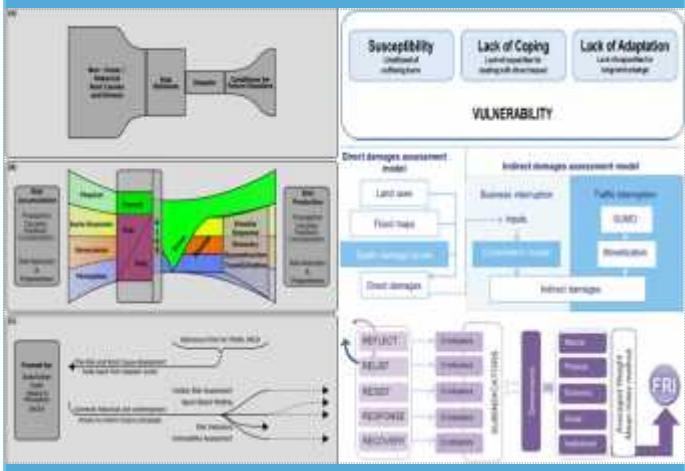
Le projet a examiné 6 études de cas à travers l'Europe et 5 pilotes des Caraïbes et d'Asie. Ceux-là étaient:

- Greve, Danemark
- Estuaire de l'Elbe, Allemagne
- Les Boucholeurs, France
- Gênes, Italie
- Marbella, Espagne
- Réthymnon, Crète, Grèce
- Saint-Martin
- Sainte-Lucie
- Tohoku, Japon
- Taïwan
- Ayutthaya, Thaïland

Les activités de recherche menées dans le cadre du projet ont fourni une pléthore de produits. cadres méthodologiques, outils et applications, ainsi que des notes d'orientation et des publications. Les plusindicatifs étaient:

- Cadre d'évaluation des risques et des causes profondes
- Cadred'évaluation de lavulnérabilité
- Des concepts novateurs d'évaluation et de modélisation des dangers pour des événements extrêmes individuels ou combinés et plusieurs échelles
- Cadres pour l'impact / dommages (directs / indirects, tangibles / intangibles), évaluation de l'impact économique et de la santé publique en raison de causes et de scénarios multiples
- Boîte à outils pour l'évaluation holistique / à risques multiples et l'évaluation des impacts / dommages niveaux stratégique et opérationnel
- Systèmes d'alerte précoce opérationnels et nouvelles méthodologies pour leur diffusion efficace
- Nouvelles méthodologies et concepts pour réaliser des simulations plus rapides et pour l'analyse de propagation d'incertitude
- Cadres pour l'analyse et l'engagement des parties prenantes, c'est-à-dire les alliances d'apprentissage et d'action
- Cadres et outils pour l'évaluation de la résilience aux inondations des systèmes urbains
- Base de connaissances intelligente pour les mesures de résilience et les stratégies et outils / algorithmes soutenant leur sélection
- Plate-forme interactive d'apprentissage et de planification sur le Web
- Des feuilles de route de gestion des risques spécifiquement adaptées aux besoins des études de cas
- Infrastructure de système d'information pour les données et la gestion des données méta.

LE PROJET PEARL: Méthodes et outils



Methodologies / Méthodologies

Tools & Application / Outils et application

Publications & Policy Briefs / Publications et notes d'information

PROBLEM DESCRIPTION, ISSUES & CHALLENGES

The area Les Boucholeurs is a fishing district located in the south part of Chatelaillon-Plage, a commune of Charente-Maritime department located in the south west of France. After the presentation of PEARL project to the commune of Chatelaillon-Plage the case study area is expanded overall commune.

The significance of this case study area is the extreme event Xynthia and its effect on the social, economic, natural, institutional and physical dimensions.

This coastal case study has area of 6.9km^2 and 6049 residents (based on the 2008 census). Known by the mussel and oyster farms the district Les Bouchelours is located on the south part of the commune Châtelaillon-Plage and on the north part of commune Yves. Originally, the district was a port located on the mouth of the Port Punay channel. Over the time (in the 20th century), this area becomes the tourist point of interest. The existing waterfront has been converted into paved promenade. The dense urbanisation started on the former site of embankment system combined with marchland (existing system of retention areas). This area was in a way a natural buffer boundary with the Atlantic coast. Its primary function was to compensate swells from the north and storms coming from the west.

The rare extreme event Xynthia occurred in early morning of 28th February 2010 as a result of atmospheric depression created on 27th February morning. This storm hint west coast of France causing large-scale floods with huge damages. Beside France, the storm hint Germany and the Benelux countries. In total 65 people died.

Described as an explosive storm with the depression of 20hpa in more than 24h, Xynthia went through the country very fast. Based on the meteorological parameters (atmospheric pressure Xynthia has not reached the exceptional storms Lothar and Martin in December 1999, neither Klaus in January 2009. Even so, the effect of Xynthia on flooding and erosion is significant, especially in the departementVandee and Charente-Maritime.

Meteorological characteristics of the storm show that the wind gust speed of Xynthia was 242 km/h at the Pic du Midi d'Ossau in the Pyrenees and in the Charente Maritime at 140 km/h.

The recorded wind speed relevant for case study is in the range from 120 km/h to 130 km/h. Excluding wind effect the tides created show significant values in heights. According to the BRGM (Bureau de RecherchesGéologiques et Minières) the measured level of 4.5 m NGF (General Levelling in France) recorded at la Rochelle (northern of case study area) corresponds to the very high return period. Up to this moment there is no official statement regarding calculated or estimated return period of this storm. The major threat for the affected area was storm surge and big waves. The storm surge was 1.6 m and the tide approximately 2.75 m.

DESCRIPTION PROBLÈME, ENJEUX ET DÉFIS

La région des Boucholeurs est un quartier de pêche situé dans la partie sud de Châtelaillon-Plage, commune du département de la Charente-Maritime située dans le sud-ouest de la France. Après la présentation du projet PEARL à la commune de Châtelaillon-Plage, la zone d'étude de cas est agrandie dans l'ensemble de la commune.

L'importance de cette zone d'étude de cas est l'événement extrême Xynthia et son effet sur les dimensions sociales, économiques, naturelles, institutionnelles et physiques.

Cette étude de cas côtière a une superficie de 6,9 km2 et 6049 résidents (selon le recensement de 2008.) Connu par les fermes de moules et d'huîtres, le quartier des Bouchelours est situé dans la partie sud de la commune de Châtelaillon-Plage et dans la partie nord de la commune Yves. A l'origine, le quartier était un port situé à l'embouchure du canal de Port Punay. Au fil du temps (au 20ème siècle), cette zone devient le point d'intérêt touristique. Le front de mer existant a été transformé en promenade pavée. L'urbanisation dense a commencé sur l'ancien site du système de remblai combiné avec marsland (système existant de zones de rétention). Cette zone était en quelque sorte une frontière tampon naturelle avec la côte atlantique. Sa principale fonction était de compenser les houles du nord et les tempêtes venant de l'ouest.

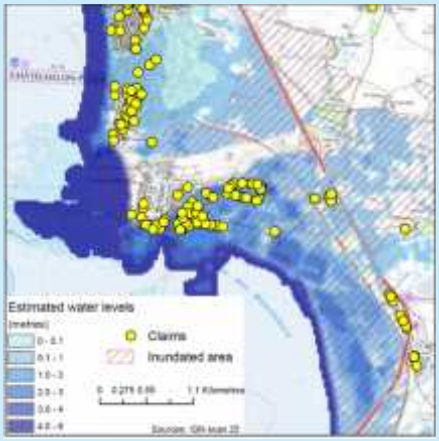
L'événement extrême rare Xynthia s'est produit tôt le matin du 28 février 2010 à la suite de la dépression atmosphérique créée le 27 février au matin. Cette tempête fait allusion à la côte ouest de la France provoquant des inondations à grande échelle avec d'énormes dégâts. A côté de la France, la tempête fait penser à l'Allemagne et au Benelux. Au total, 65 personnes sont mortes.

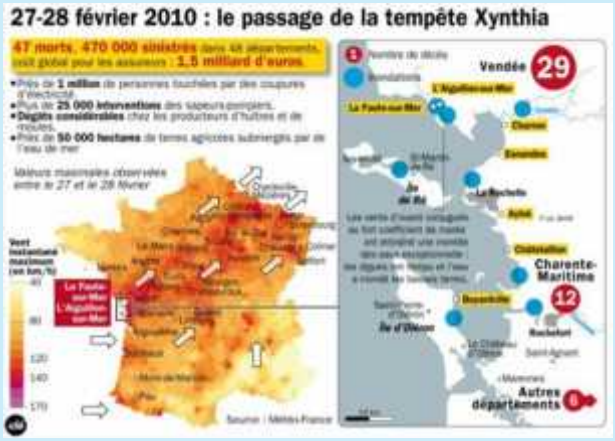
Décrite comme une tempête explosive avec la dépression de 20hpa en plus de 24h, Xynthia a traversé le pays très rapidement. Sur la base des paramètres météorologiques (pression atmosphérique Xynthia n'a pas atteint les tempêtes exceptionnelles Lothar et Martin en décembre 1999, ni Klaus en janvier 2009. L'effet de Xynthia sur les inondations et l'érosion est significatif, surtout dans le département Vandee et Charente-Maritime.

Les caractéristiques météorologiques de la tempête montrent que la vitesse du vent de Xynthia était de 242 km / h au Pic du Midi d'Ossau dans les Pyrénées et en Charente Maritime à 140 km / h.

La vitesse du vent enregistrée pour l'étude de cas est comprise entre 120 km / h et 130 km / h. En excluant l'effet du vent, les marées créées montrent des valeurs significatives en hauteur. Selon le BRGM (Bureau de Recherches Géologiques et Minières), le niveau mesuré de 4,5 m NGF (General Leveling en France) enregistré à la Rochelle (au nord de la zone d'étude de cas) correspond à la période de retour très élevée. Jusqu'à présent, il n'y a pas de déclaration officielle concernant la période de retour calculée ou estimée de cette tempête. La principale menace pour la zone touchée était les ondes de tempête et les grosses vagues. L'onde de tempête était de 1,6 m et la marée d'environ 2,75 m.

PROBLEM DESCRIPTION, ISSUES & CHALLENGES





Social situation is highly sensitive due to the difficulties and damages caused by Xynthia storm. Xynthia storm occurred in February, 2010 causing severe storm surge, demolition of the protection system and huge damages to both, people and assets.

After this event, in the hurry, the place “Les Boucholeurs” was designed as one of the main “Black Area” where all the houses should be destroyed. This impacted local community a lot due to their farming activities and living places. This causes huge social tensions and raised sensitivity of local community to any change.

Institutional framework of this area regarding flood protection is changed with the new protection plan, PAPI (Programmes d’action de prévention des inondations). Based on that change, the new protection system is built by now.

The main challenge for PEARL project is to try to apply holistic approach in ’helping’ community to understand the risks, see all vulnerable spots and have possibility to discuss about different strategies and measures that will increase flood resilience of the area.

Since we had a good data to proceed with the analysis we managed to apply developed methodology for Flood Resilience Index on three different scales: micro, meso and macro. Even more, we were able to develop several scenarios for analysis in consultations with the local community.

DESCRIPTION PROBLÈME, ENJEUX ET DÉFIS

La situation sociale est très sensible en raison des difficultés et des dommages causés par la tempête Xynthis. La tempête Xynthia s'est produite en février 2010, provoquant une forte onde de tempête, la démolition du système de protection et d'énormes dommages à la fois aux personnes et aux biens.

Après cet événement, pressé, l'endroit "Les Boucholeurs" a été conçu comme l'un des principaux "quartier noir" où toutes les maisons devraient être détruites. Cela a beaucoup affecté la communauté locale en raison de ses activités agricoles et de ses lieux de vie. Cela provoque d'énormes tensions sociales et augmente la sensibilité de la communauté locale à tout changement.

Le cadre institutionnel de cette zone en matière de protection contre les inondations est modifié avec le nouveau plan de protection, le PAPI (Programme d'Action de Prévention des Inondations). Basé sur ce changement, le nouveau système de protection est construit maintenant.

Le principal défi pour le projet PEARL est d'essayer d'appliquer une approche holistique pour «aider» la communauté à comprendre les risques, à voir tous les points vulnérables et à discuter des différentes stratégies et mesures qui augmenteront la résilience aux inondations de la zone.

Comme nous avions de bonnes données pour procéder à l'analyse, nous avons réussi à appliquer la méthodologie développée pour l'indice de résilience aux inondations à trois échelles différentes: micro, méso et macro. Plus encore, nous avons pu développer plusieurs scénarios d'analyse en concertation avec la communauté locale.

PEARL OUTCOMES& STAKEHOLDERS' PARTICIPATION

The research activities for Chantellailon-Plage case study focuses on holistic risk assessment and flood resilience evaluation. The general objective after data collection and modelling phase was a focus on flood risk management with final goal to provide usable forms for communication with key stakeholders. The analysis and general definition of frameworks for vulnerability, risk and resilience is done within Arc GIS.

Research activities are focused on vulnerability and risk mapping. However, the additional requirement was to have availability to map both risk and vulnerability. The framework developed for vulnerability takes into account *population vulnerability, socio-economic vulnerability and vulnerability of build environment*. This was chosen in order to enable spatial representation of results. Each vulnerability parameter has associated impact element.

Communication with stakeholders was used to present our results to stakeholders. We had a positive feedback. What was marked as very acceptable is the fact that we created spatial presentation of results. With the framework developed for vulnerability and risk we created the maps showing vulnerability and risk value for every building the in area.

In addition, we managed to create maps for three different scenarios. In the figures below the result maps are shown for vulnerability and risk.

The developed framework has a great acceptance from local community. Spatial representation of results is more understandable for non-scientific or non-engineering persons.

Les activités de recherche pour l'étude de cas de Chantellailon-Plage se concentrent sur l'évaluation holistique des risques et l'évaluation de la résilience aux inondations. L'objectif général, après la phase de collecte et de modélisation des données, était de mettre l'accent sur la gestion des risques d'inondation avec pour objectif final de fournir des formulaires utilisables pour la communication avec les principales parties prenantes. L'analyse et la définition générale des cadres de vulnérabilité, de risque et de résilience sont réalisées dans Arc GIS.

Les activités de recherche sont axées sur la vulnérabilité et la cartographie des risques. Cependant, l'exigence supplémentaire était d'avoir la disponibilité pour cartographier à la fois le risque et la vulnérabilité. Le cadre développé pour la vulnérabilité prend en compte la vulnérabilité de la population, la vulnérabilité socio-économique et la vulnérabilité de l'environnement de construction. Ceci a été choisi pour avoir la possibilité d'avoir une représentation spatiale des résultats. Chaque paramètre de vulnérabilité a un élément d'impact associé.

La communication avec les parties prenantes a été utilisée pour présenter nos résultats aux parties prenantes. Nous avons eu une réaction positive. Ce qui a été marqué comme très acceptable, c'est le fait que nous avons créé une présentation spatiale des résultats. Avec le cadre développé pour la vulnérabilité et le risque, nous avons créé les cartes montrant la vulnérabilité et la valeur du risque pour chaque bâtiment dans la zone.

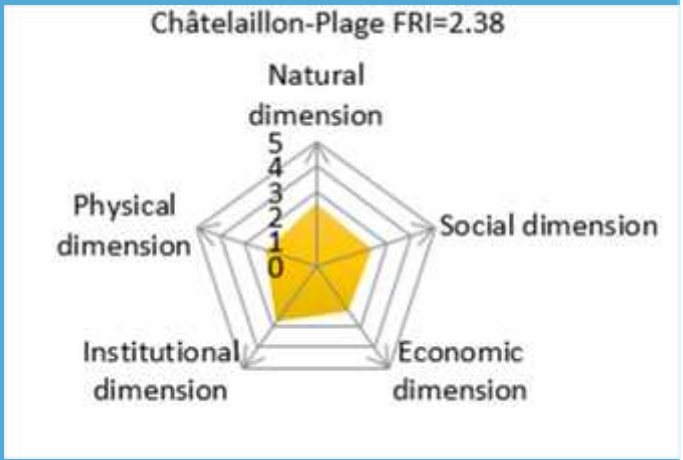
En outre, nous avons réussi à créer des cartes pour trois scénarios différents. Dans les figures ci-dessous, les cartes de résultats sont montrées pour la vulnérabilité et le risque.

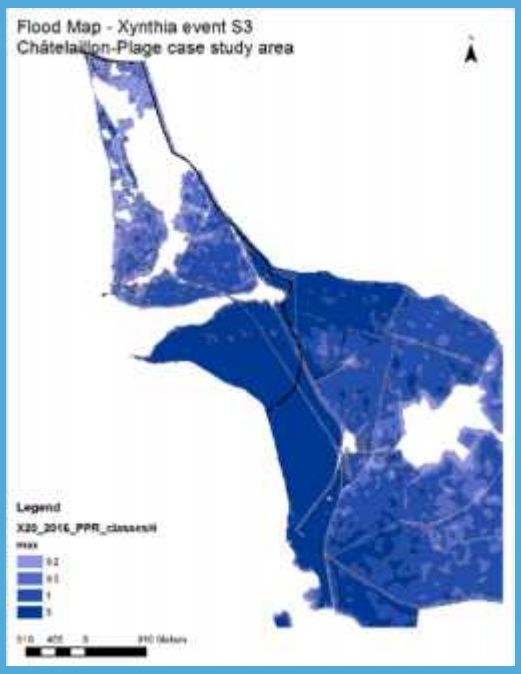
Le cadre développé est très bien accepté par la communauté locale. La représentation spatiale des résultats est plus compréhensible pour les personnes non scientifiques ou non-ingénieurs.

RÉSULTATS DE PERLE & PARTICIPATION DES PARTIES PRENANTES

UF	Number	Total Damage (Euro)
Education	2	94 941.18
Food	3	705 871.11
Governance	5	317 389.19
Health	0	-
Housing	1660	17 795 886.84
Leisure	2	56 943.22
Religion	1	5 010.28
Transport	1	34 862.6
Working	34	1 380 037.26
Mixed	14	920 083.11
Sum	1722	21 311 024.79

GROUP OF ACTIVITIES 1: Strengthening information & raising flood risk awareness





Targets made at the beginning of the project were too optimistic. Having in mind serious social component in approaching relevant stakeholders and talk about flood risk and what actions should be made.

Most stakeholders are not willing or allowed to be part of LAA, therefore the LAA is reduced in smaller groups on local level. This comes from the fact that Xynthia storm was extreme in terms of damages, the level of destruction and on influence on farming activities (huge social impact also). There are ongoing court processes so a very sensitive situation. Up to now the communication channel is created with mayor of Châtelaillon-Plage. At this point we are having positive feedback on the analysis done.

Round of meetings with the stakeholders in Châtelaillon-Plage was on April 2015 and June 2016. Meeting held on April 2015 is within the 1st scientific report. The last meeting with the local stakeholders is done in November 2017. The project results presented to the city officials are accepted positively. In addition the cooperation will continue on next H2020 project (RECONECT).

The following action will be made in the future:

- Exploring an innovative green and blue infrastructure towards increased resilience to existing risks
- Following reconstruction and improvement of existing structural protection (protection wall)

In addition, after Xynthia event, the community had a hard time to cope with the damages. The process of recovery was mainly focused on:

- Hydraulic works at the level of the channel of Port Punay and - One of the banks of the canal has been reinforced and stabilized upstream of the Port Punay road, to prevent collapse and improve water flow,
- Hydraulics works on rainwater networks - The entire storm network is being re-started,
- Maritime works along the coast of Boucholeurs - Blade breakers (more than 80,000 tons of rocks, each breakwater is 170m long and 20m wide. They are spaced 50m apart),
- Urban development and landscaping - modification of the existing traffic plan in order to adapt more space for pedestrians,

To summarize, the big effect had maps produced for direct damage assessment, flood risk, vulnerability and flood resilience on building and city scale.

The maps provided a solid tool for communication with the stakeholders and contribute to building capacity of local community for better understanding current risk of extreme events in their area.

GROUPE D'ACTIVITÉS 1: Renforcement de l'information et sensibilisation aux risques d'inondation

Ayant à l'esprit une composante sociale sérieuse dans l'approche des parties prenantes concernées et de parler des risques d'inondation et quelles actions devraient être faites.

La plupart des parties prenantes ne veulent pas ou ne peuvent pas faire partie de la LAA, par conséquent la LAA est réduite en petits groupes au niveau local. Cela vient du fait que la tempête Xynthia était extrême en termes de dommages, de niveau de destruction et d'influence sur les activités agricoles (impact social énorme aussi). Il y a des processus judiciaires en cours, donc une situation très délicate. Jusqu'à présent, le canal de communication est créé avec le maire de Châtelaillon-Plage. À ce stade, nous avons des commentaires positifs sur l'analyse effectuée.

Une série de réunions avec les parties prenantes à Châtelaillon-Plage a eu lieu en avril 2015 et en juin 2016. La réunion d'avril 2015 fait partie du 1er rapport scientifique. La dernière réunion avec les parties prenantes locales a lieu en novembre 2017. Les résultats du projet présentés aux responsables de la ville ont été particulièrement bien reçus et une extension de l'approche est envisagée dans le cadre de la Communauté de Communes de La Rocelle. De plus, la coopération se poursuivra sur le prochain projet H2020 (RECONECT).

Les actions suivantes seront faites à l'avenir:

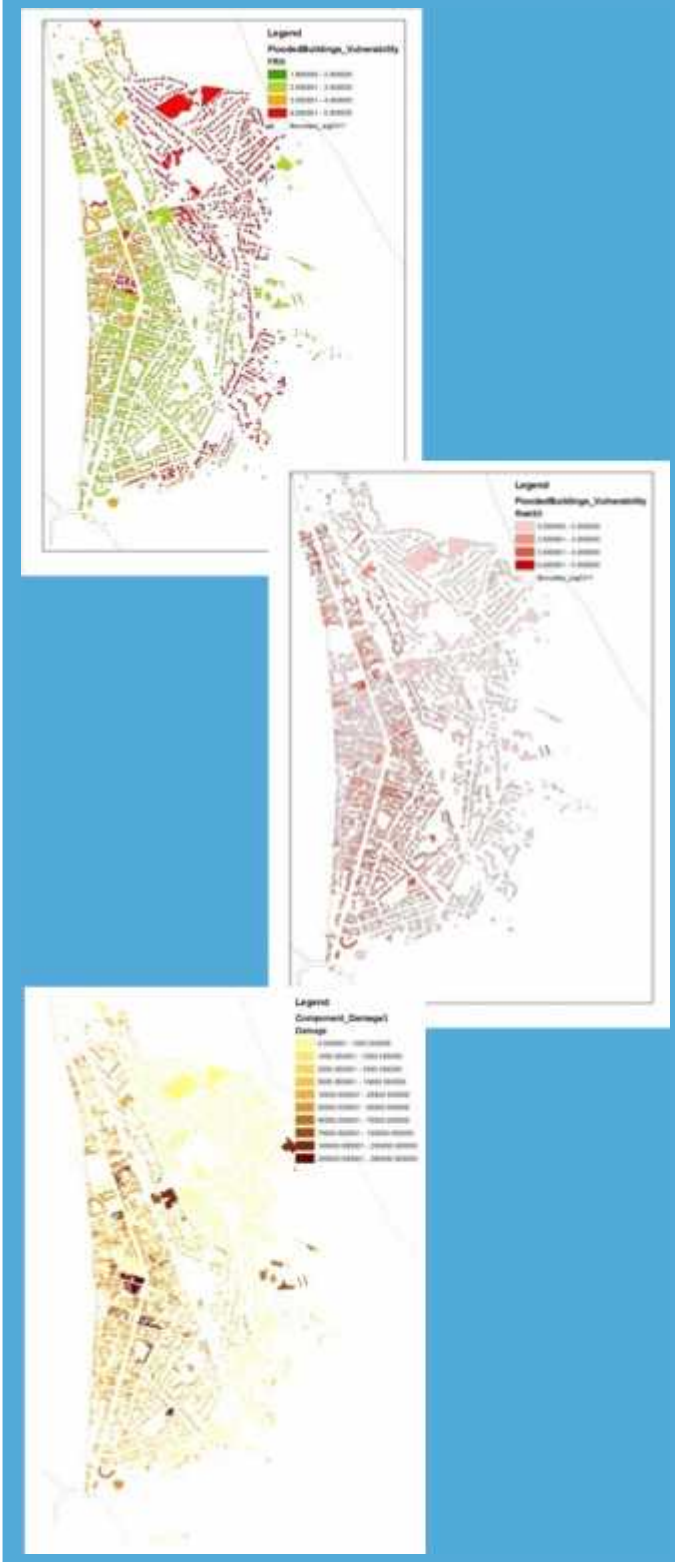
- Explorer une infrastructure verte et bleue innovante vers une résilience accrue aux risques existants
- Suite à la reconstruction et l'amélioration de la protection structurelle existante (mur de protection)

En outre, après l'événement Xynthia, la communauté a eu du mal à faire face aux dommages. Le processus de récupération était principalement axé sur:

- Construction d'ouvrages hydrauliques au niveau du canal de Port Punay : une des berges du canal a été renforcée et stabilisée en amont de la route de Port Punay, pour éviter l'effondrement et améliorer le débit,
- Amélioration des réseaux pluviaux: l'ensemble du réseau pluvial est restauré et optimisé,
- Travaux maritimes de protection le long de la côte des Boucholeurs: brise-lames (plus de 80 000 tonnes de roches, chaque brise-lames mesure 170 m de long et 20 m de large, espacés de 50 m),
- Aménagement urbain et aménagement paysager: modification du plan de circulation existant afin d'adapter l'espace et offrir plus d'espace pour les piétons.

Pour résumer, des cartes produites dans le cadre du projet pour l'évaluation directe des dommages, le risque d'inondation, la vulnérabilité et la résilience face aux inondations à l'échelle du bâtiment et de la ville ont été diffusées et largement utilisées dans la réflexion de la commune pour ses différents plans de gestion.

Les différentes cartes ont fourni des outils efficaces et solide pour la communication avec les parties prenantes et ont contribué au renforcement des capacités de la communauté locale pour une meilleure compréhension du risque actuel face aux événements extrêmes susceptibles d'intervenir dans la région.



LESSONS LEARNED, RESULTS & DISCUSSION

Following the storm Xynthia in 2010, the commune of Châtelaillon-Plage set up, with the commune of Yves, Aix and Fouras, a system of fight against the different types of floods combining a PAPI (Program of Actions of Flood Prevention), a PCS (Municipal Protection Plan) and a union to develop protection measures, inform the population and have an effective management structure in case of a new event. This approach is largely inspired by the lessons learned following the storm Xynthia and helps to strengthen the resilience of the municipality and the exposed populations.

The procedure adopted jointly by the municipalities' aims to protect people, property and activities against the risks of marine submersion.

The main stages of implementation are:

- Establishment of a PAPI (Flood Prevention Action Program) in the regulatory framework,
- Better know the risks in the municipality with a Municipal Protection Plan (PSC): the municipality of Châtelaillon-Plage has implemented its Municipal Protection Plan (PCS) under the authority of the Mayor for each specific risk (storm, submersion) , strong, wind, etc.). It is about "getting ready to be ready" so that the exposed people know what to do in case of an alert (orange / red), how to manage the risk, where to be safe as well as the organization of the responsibilities for them. managers of the crisis. This procedure, which defines the way in which the municipality must act in the event of a crisis, is specific to each risk: storm, submersion, strong wind, etc. Tests and simulations are performed at least once a year to ensure the operational aspect of this crisis management tool.
- Establishment of the SILYCAF union (Yves-Châtelaillon-Aix-Fouras Coastal Union): this public structure, common to the various coastal municipalities, federates resources to ensure the protection of people and property against the risks of marine submersion on the entire coastline of Yves Bay. The main activities of SYLICAF are:
    - Provide technical, administrative and financial monitoring of the different projects,
    - Implementation of knowledge tools for the definition of protection and defense measures against floods (PAPI),
    - Creation of protection works (project manager),
    - Supervise and maintain protective work,
    - Maintain the crisis management system operational,
    - Actions for the development of prevention.

The results of the PEARL project are important contributions that are now used by SILYCAF in the framework of its missions.

Further, the application of FRI is accepted from technical staff in case study area. Activities regarding FRI will be focused for capacity building of human resources in case study. The educational workshops are planned where the main objective will be raising awareness.

Suite à la tempête Xynthia en 2010, la commune de Châtelaillon-Plage a mis en place, avec la commune d'Yves, Aix et Fouras, un dispositif de lutte contre les différents types d'inondations combinant un PAPI (Programme d'Actions de Prévention des Inondations), un PCS (Plan de Protection Municipal) et un syndicat de travaux destiné à développer les mesures de protection, informer la population et se doter d'une structure de gestion efficace en cas de nouvel évènement. Cette démarche s'inspire largement des enseignements tirés suite à la tempête Xynthia et contribue à renforcer la résilience de la commune et des populations exposées.

La procédure retenue conjointement par les communes a pour but de protéger les personnes, les biens et les activités contre les risques de submersion marine.

Les principales étapes de la mise en œuvre sont:

- Mise en place d'un PAPI (Programme d'Actions de Prévention des Inondations) dans le cadre réglementaire,
- Mieux connaitre les risques dans la commune avec un Plan Municipal de Protection (PSC): la commune de Châtelaillon-Plage a mis en place son Plan de Protection Municipal (PCS) sous l'autorité du Maire pour chaque risque spécifique (tempête, submersion, fort, vent, etc.). Il s'agit de «s'organiser pour être prêt» afin que les personnes exposées sachent quoi faire en cas d'alerte (orange / rouge), comment gérer le risque, où être en sécurité ainsi que l'organisation des responsabilités pour les gestionnaires de la crise. Cette procédure, qui définit la manière dont la commune doit agir en cas de crise, est spécifique à chaque risque: tempête, submersion, vent violent, etc. Des tests et des simulations sont effectués au moins une fois par an pour assurer l'aspect opérationnel de cet outil de gestion de crise.
- Mise en place du syndicat SILYCAF (Syndicat du Littoral Yves-Châtelaillon-Aix- Fouras): cette structure publique, commune aux différentes communes littorales, fédère les ressources afin d'assurer la protection des personnes et des biens contre les risques de submersion marine sur tout le littoral de la baie Yves. Les principales activités de SYLICAF sont:
  - Assurer le suivi technique, administratif et financier des différents projets,
  - Mise en place des outils de connaissances pour la définition des mesures de protection et de défense contre les inondations (PAPI),
  - Création de travaux de protection (chef de projet),
  - Superviser et maintenir les travaux de protection,
  - Maintenir le système de gestion de crise opérationnelle,
  - Développer des actions de prévention.

Les résultats du projet PEARL sont des contributions importantes qui sont aujourd'hui utilisées par le SILYCAF dans le cadre de ses missions.

En outre, l'application de la FRI est acceptée par le personnel technique dans la zone d'étude de cas. Les activités concernant le FRI seront axées sur le renforcement des capacités des ressources humaines dans l'étude de cas. Les ateliers de formation sont prévus où l'objectif principal est la sensibilisation.

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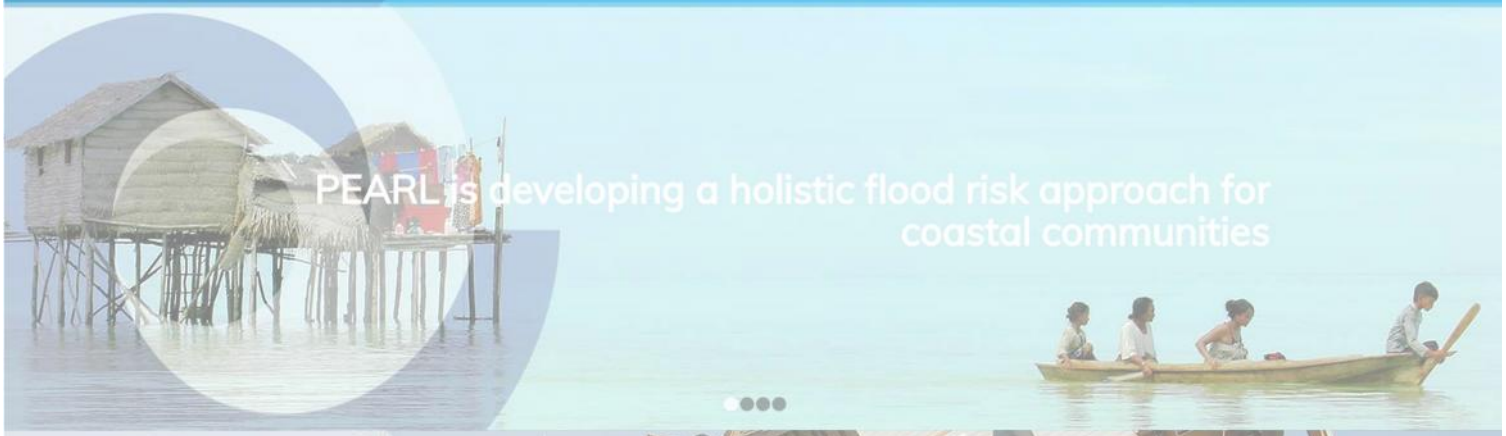
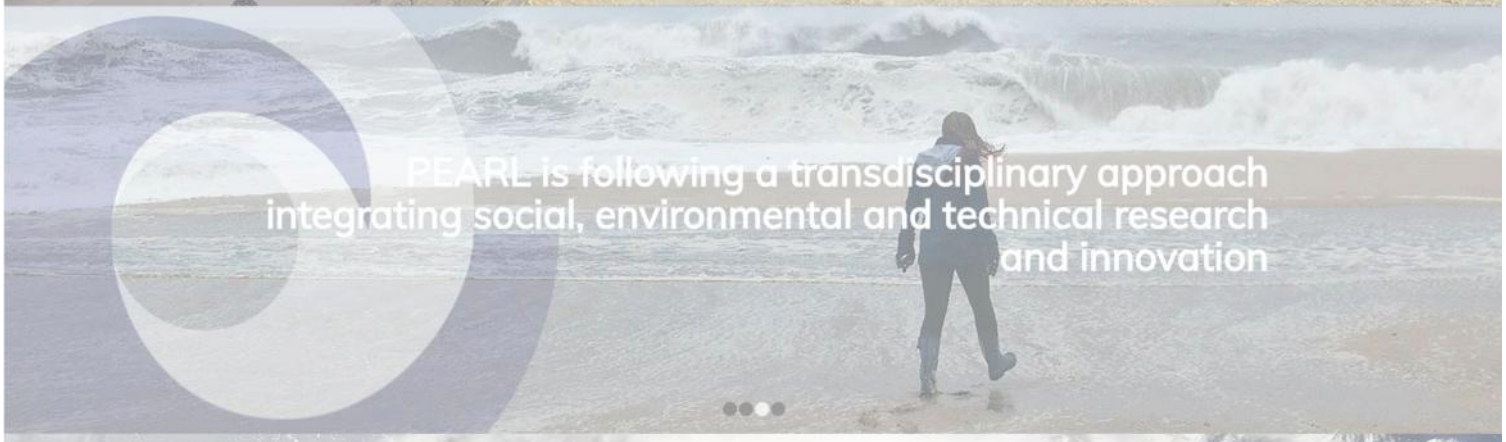
Preparing for Extreme And Rare events in coastaL regions

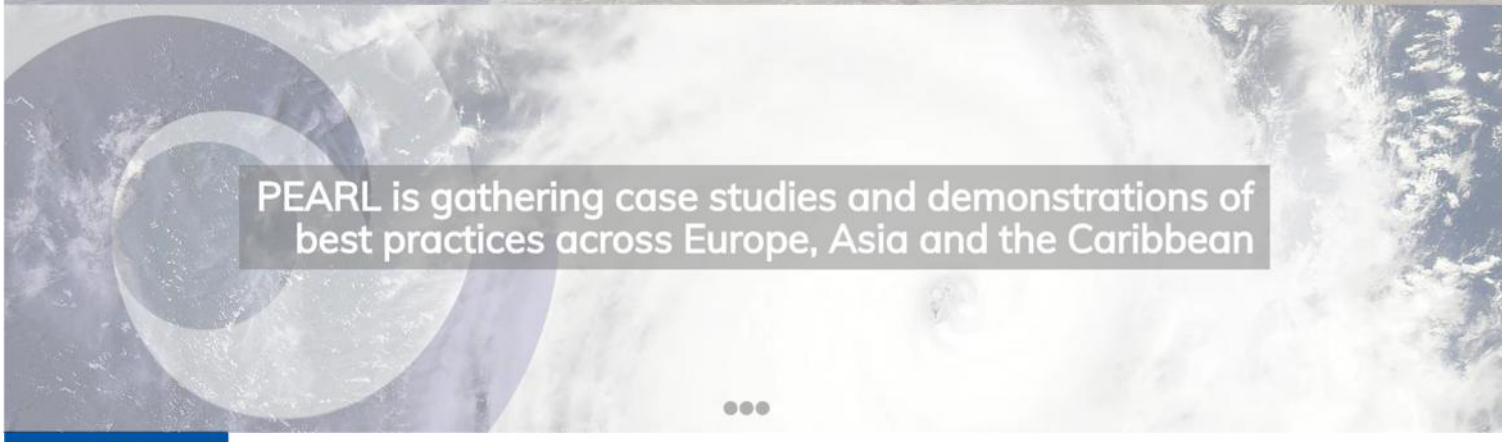


PEARL is developing a holistic flood risk approach for coastal communities

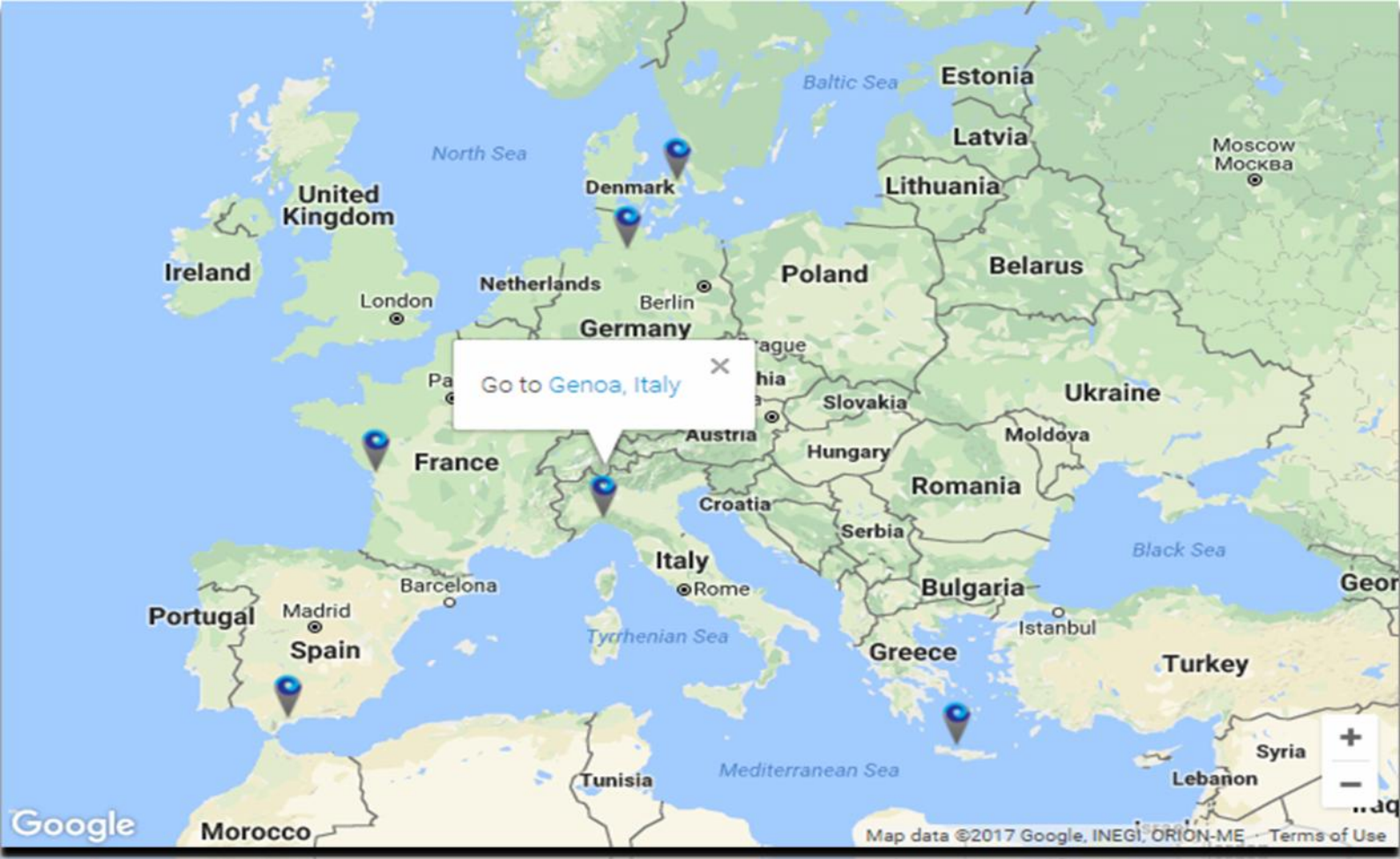
PEARL is improving forecasting, prediction and early warning capabilities



PEARL is following a transdisciplinary approach integrating social, environmental and technical research and innovation



PEARL is gathering case studies and demonstrations of best practices across Europe, Asia and the Caribbean



Risk Management Roadmap for the case study of Genoa, Italy

GISIG – Geographical Information Systems International Group

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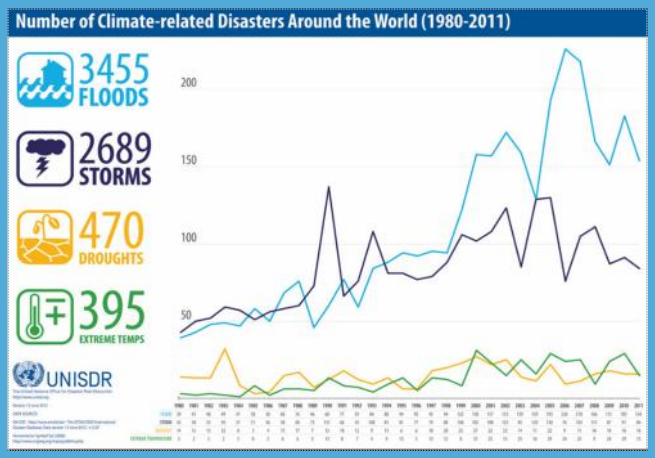
Preparing for Extreme And Rare events in coastaL regions

FLOOD RISK & FLOOD RISK MANAGEMENT

Genoa flood - 1970



Statistics/Statistica

Flood types/Tipologie di inondazione

Coastal floods are regarded as one of the most dangerous and harmful of all natural disasters. Rapid urbanisation in coastal areas combined with climate change and poor governance can lead to a significant increase in the risk of local pluvial flooding coinciding with high water levels in rivers and high tide or storm surges from the sea, posing a greater risk of devastation in coastal communities.

There is a need to improve forecasting, prediction and early warning capabilities using state of art science and technology to help policy makers and emergency services to develop robust risk reduction strategies. However, forecasting and prediction is only part of the answer. Of equal importance is the ability to effectively warn the population in areas that will be affected, and that warning systems for the general public are integrated into broader management strategies and supported by appropriate institutional and organisational arrangements. Preparing for effective response to extreme events not only involves technology but also significantly social, economic, organisational and political considerations.

Flood risk management aims to reduce the likelihood and/or the impact of floods. Experience has shown that the most effective approach is through the development of flood risk management programmes incorporating the elements of prevention, protections, preparedness, emergency response, recovery and lessons learned. Reducing human casualties and damage to economic activity and the environment are key objectives shared by all EU countries and implementation of the 2007 Floods Directive has an important role in making this happen.

The Directive applies to all kinds of floods (river, lakes, flash floods, urban floods, coastal floods, including storm surges and tsunamis) and it is being implemented in a three-base process i.e. the preliminary flood risk assessment, the development of floods hazard and flood risk maps and eventually the production of flood risk management plans. River Basin Districts are the main units for the management of river basins, as described within the Water Framework Directive, therefore, they were adopted for the EU Flood Directive too.

Flood maps are being used by many different stakeholders within flood risk management and serve purposes related to prevention of the build-up of new risk, reduction of existing ones and adaptation to changing risk factors. Development and use of flood maps serves multiple purposes such as conduction of flood risk management plans, land use planning and land management, emergency planning, public awareness raising and within the private sector e.g. insurance assessment and pricing.

Floods, among others, are commonly referred to as natural disasters but they are not in fact the results of nature-related processes alone. They are to an ever-increasing extent directly attributable to various social, economic, historical, political and even cultural issues. The perception of flood impact on life and daily activities can be significantly different amongst the population and the level of knowledge and understanding of flood risk in a given area is directly related to people's decisions to either adjust their living to such a risk or simply to ignore it.

The PEARL project sought to fill in the lack of interaction between social aspects and technical measures – appearing to be a major hindrance for solving some of the greatest problems associated with floods and flood-related disasters.

http://www.pearl-fp7.eu/

INONDAZIONI & GESTIONE DEL RISCHIO ALLUVIONALE

Le alluvioni in zone costiere sono annoverate tra i disastri naturali più pericolosi e dannosi. La rapida urbanizzazione che ha interessato le aree costiere, combinata ai cambiamenti climatici e un governo del territorio non efficace possono aumentare il rischio di alluvioni localizzate dovute alla pioggia intensa, all'innalzamento del livello dei fiumi e dei mari per via delle maree meteorologiche, mettendo a rischio le comunità costiere o causando devastazioni.

C'è necessità di migliorare la previsione, la predizione e i sistemi di allertamento, sfruttando lo stato dell'arte della scienza e delle tecnologie per aiutare legislatori ed enti di Protezione Civile a sviluppare robuste strategie di riduzione del rischio. Tuttavia, previsione e predizione è solo una parte di quello che serve. Di uguale importanza è la capacità di allertare efficacemente la popolazione delle aree che saranno colpite, e che i sistemi di allertamento al pubblico siano integrati in più ampie strategie e supportati da appropriate iniziative istituzionali e organizzative. Prepararsi per una risposta efficace agli eventi estremi non implica solo l'uso della tecnologia, ma anche considerazioni di carattere sociale, economico, organizzativo e politico.

La gestione del rischio alluvionale vuole ridurre la propensione e gli impatti da alluvioni. L'esperienza ha dimostrato che l'approccio più efficace è attraverso lo sviluppo di un programma di gestione del rischio, che incorpora gli elementi di prevenzione, protezione, preparazione, risposta alle emergenze e ripristino. La riduzione della perdita di vite umane e i danni alle attività economiche sono gli obiettivi chiave condivisi da tutti i paesi UE e l'implementazione della Direttiva Alluvioni del 2007 ha avuto un ruolo importante nel loro raggiungimento.

La Direttiva si applica a tutti i tipi di inondazioni (fiumi, laghi, alluvioni lampo, alluvioni urbane, alluvioni costiere…) ed è implementata su tre livelli distinti: la valutazione preliminare del rischio alluvionale, lo sviluppo di mappe di pericolosità e di rischio alluvionale, la produzione di piani di gestione del rischio. Le Autorità di Distretto sono le istituzioni principali adibite alla gestione del bacino, come recita la Direttiva Quadro sulle Acque, e sono state riconosciute anche dalla Direttiva Alluvioni.

Le mappe di inondazione sono usate da diversi attori nell'ambito della gestione del rischio alluvionale, e hanno lo scopo di prevenire nuovi rischi, ridurre quelli esistenti e di adattarsi ai cambiamenti in atto. Lo sviluppo e l'uso di mappe di inondazione ha differenti scopi tra cui la definizione di piani di gestione del rischio alluvionale, pianificazione e gestione dell'uso del suolo, piani di Protezione Civile, sensibilizzazione dei cittadini, definizione di prodotti e premi assicurativi.

Le alluvioni sono disastri naturali, ma gli impatti sono associati a fattori sociali, economici, storici, politici e culturali. La percezione del rischio e degli impatti sulle attività quotidiane infatti differisce significativamente tra la popolazione e il livello di conoscenza e di adattamento è a discrezione del singolo individuo.

Il progetto PEARL ambisce a creare una collegamento tra aspetti sociali e soluzioni tecniche – la cui mancanza risulta essere uno degli ostacoli maggiori per risolvere molti dei problemi associati all alluvioni e ai disastri alluvionali.

Storm supercell/supercella temporalesca

Costal flood/Mareggiata

Warning system/ Sistema di allerta

THE PEARL PROJECT: Methods & Tools

PEARL Project / Il Progetto PEARL

Case Studies / Caso Studio

Partners / Consorzio

The PEARL project, a collaborative research project with 4year duration, worked towards the development of adaptive, sociotechnical risk management measures and strategies for coastal communities against extreme hydro-meteorological events minimising social, economic and environmental impacts and increasing the resilience of Coastal Regions in Europe. PEARL received funding from the European Union's Seventh Framework Programme for Research, Technological Development and Demonstration (EU-FP7) under the theme "Coasts at threat in Europe: tsunamis and climate-related risks" (ENV.2013.6.4-3).

The PEARL consortium consisted of 24 partners from 13 countries from Europe and Asia, with significant experiences of severe flood risk in coastal regions and advanced flood early warning systems. Project's leader was the UNESCO-IHE.

The project examined 6 case studies from across Europe and 5 pilots from the Caribbean and Asia. Those were:

- Greve, Denmark
- Elbe Estuary, Germany
- Les Boucholeurs, France
- Genoa, Italy
- Marbella, Spain
- Rethymno, Crete, Greece
- St. Maarten
- St. Lucia
- Tohoku, Japan
- Taiwan
- Ayutthaya, Thailand

The research activities which were conducted within the project provided a plethora of products i.e. methodological frameworks, tools and applications, as well as policy briefs and publications. The most indicative ones were:

- Risk and Root Cause Assessment framework
- Vulnerability assessment framework
- Innovative hazard assessment and modelling concepts for individual or combined extreme events and several scales
- Frameworks for impact/damages (direct/indirect, tangible/intangible), economic and public health impact assessment due to multiple causes and scenarios
- Toolkit for holistic/multiple risk and impact/damage assessment at strategic and operational levels
- Operational Early Warning Systems and new methodologies for their effective dissemination
- Novel methodologies and concepts for achieving faster simulations and for uncertainty propagation analysis
- Frameworks for stakeholders' analysis and engagement i.e. the Learning and Action Alliances
- Frameworks and tools for flood resilience assessment of urban systems
- Intelligent knowledge base for resilience measures and strategies and tools/algorithms supporting their selection
- Interactive web-based learning and planning platform
- Risk Management Roadmaps specifically tailored to case study needs
- Information system infrastructure for data and meta data management

All outcomes/products and their integration formed the holistic approach and eventually the PEARL holistic framework enhancing prevention, mitigation and preparedness capabilities and building flood resilience of coastal urban systems.

http://www.pearl-fp7.eu/

Il progetto PEARL, iniziativa di ricerca della durata di 4 anni, ha lavorato per sviluppare misure adattative e socio-tecniche di gestione del rischio e strategie per le comunità costiere contro eventi idro-meteorologici estremi allo scopo di minimizzare gli impatti sociali, economici e ambientali e aumentare la resilienza delle regioni costiere in Europa. PEARL è stato co-finanziato dall'Unione Europea nell'ambito del Settimo Programma Quadro per la Ricerca, lo Sviluppo Tecnologico e la Dimostrazione (EU-FP7) al tema "Coste e minacce in Europa: tsunami e rischi connessi al clima" (ENV.2013.6.4-3).

Il consorzio di PEARL è costituito da 24 partners da 13 paesi di Europa e Asia, con significativa esperienza di gestione dei rischi di inondazione in regioni costiere e di sistemi avanzati di allertamento. Coordinatore del progetto è UNESCO-IHE.

Il progetto ha sviluppato 6 casi di studio in Europa e 5 pilota nei Caraibi e in Asia, che sono:

- Greve, Danimarca
- Fiume Elba, Germania
- Les Boucholeurs, Francia
- Genova, Italia
- Marbella, Spagna
- Rethymno, Creta, Grecia
- St. Maarten
- St. Lucia
- Tohoku, Giappone
- Taiwan
- Ayutthaya, Tailandia

Le attività condotte nel progetto hanno sviluppato differenti prodotti tra metodologie, strumenti e applicazioni, così come direttive e pubblicazioni. I prodotti più significativi sono:

- Metodologia di valutazione del rischio e delle relative cause
- Metodologia di valutazione della vulnerabilità
- Valutazione innovativa della pericolosità e modelli per simulazione di eventi singoli o combinati a differenti scale
- Metodologie per la valutazione degli impatti e dei danni (diretti/indiretti, tangibili/intangibili), valutazione degli impatti economici e sulla salute pubblica, connessi a molteplici cause e scenari
- Toolkit per valutazione olistica/multipla dei rischi e degli impatti/danni a livello strategico e operativo
- Sistemi di Early Warning e nuove metodologie per una loro efficace disseminazione
- Nuove metodologie e concetti per eseguire modellazioni più veloci e per l'analisi di propagazione delle incertezze
- Metodologia per l'analisi e il coinvolgimento degli stakeholders, ad esempio le *Learning and Action Alliances*
- Metodologie e strumenti per la valutazione della resilienza alle alluvioni da parte di sistemi urbani
- Base di conoscenza su misure di resilienza, strategie e strumenti/algoritm per supportare la loro
- Piattaforma web interattiva per la formazione e la pianificazione
- Roadmap per la *gestione* del rischio, specifica per le esigenze dei siti pilota
- Infrastruttura di un sistema informative per la gestione di dati e metadati

Tutti i prodotti, e i risultati della loro integrazione, costituiscono l'approccio olistico e, se vogliamo, la metodologia olistica di PEARL per stimolare le capacità di prevenzione, di mitigazione e di preparazione e costruire la resilienza alle alluvioni nei sistemi urbani costieri.

IL PROGETTO PEARL: Metodi & Strumenti

Greve case study/Caso Studio Greve

Marbella case study/Caso Studio Marbella

St. Maarten case study/Caso studio St. Maarten

PROBLEM DESCRIPTION, ISSUES & CHALLENGES

Flooded area 2014/Aree inondate 2014

Structural ongoing works/Interventi idraulici in atto

Works for a by-pass channel/Lavori scolmatore

Genoa is the Liguria county seat, situated in North western Italy. It is located in the Gulf of Genoa on the Ligurian Sea and is the sixth largest city in Italy with an estimated population of 585.000 inhabitants and area of 240 km^2. Genoa is one of Europe's largest cities on the Mediterranean Sea and the largest seaport in Italy is located here. The PEARL project focusses on the last 5 km of the Bisagno, which is one of the most problematic rivers of the region in terms of floods (Faccini et al. 2016). The Bisagno river basin is set in an area with complex geomorphology and large elevation changes upstream which are the driving forces for flooding related issues in its downstream urban area. The risk of flooding is further increased by the high degree of urbanization that over the years considerably modified the natural path of the river. Around 1930, the last 1.3 km of the river (from Brignole railway station to the mouth) was covered in order to construct buildings and streets. This resulted in a decrease of discharge capacity and increase of flood occurrence in the urban area.

The combination effects among Bisagno river basin morphology, man-made modifications to urban area and locally generated extreme hydro-meteorological events (heavy precipitations, V-shaped storms) are the main causes of pluvial and flash floods that hit the city along the years. Last flood event that hit the city of Genoa occurred in October 2014. Besides this event, most recent flood events in Genoa city took place in 2010 and 2011. After the Second World War notable events occurred in 1951, 1953, 1970 and 1992 (Faccini et al. 2015). All events resulted in displacement of people and high economic damage and in many cases also in fatalities.

Urban Flooding are a great disturbance of Genoa daily life. Roads can be blocked; people can't go to work or to schools. Some areas are on flat terrain and so the flow speed is low and you can still see people driving car or scoter through ponding water. Other areas of the city are on sloping terrain and it's common that the water quickly flowing on the city streets due to high slopes. The streets become drainage networks and this flow doesn't go into the river due to banks or other obstacles. It's happen that water depth is not deep but velocity doesn't allow citizens to walk. The economic damages are high but the number of casualties is usually very limited, because of the nature of the flood. The propagation and extent of Urban Flooding in Genoa are obviously a function of the intensity of the event, but it is a fact that is sufficient a rainfall that does not cause a riverine flood.

PEARL project wants to contribute to study generation and impacts by extreme events, and to properly assess, into a holistic view, the vulnerability and risk of the Bisagno area, in order to push towards a good management and planning and increase flood resilience at urban and citizens level.

DESCRIZIONE DEL CASO DI STUDIO

IL CONTESTO, I PROBLEMI & LE SFIDE

Genova è il capoluogo della Liguria, nel nord-est dell'Italia. Si posiziona sull'omonimo golfo nel Mar Ligure, ed è la sesta città italiana più grande, con una popolazione di circa 585.000 abitanti ed un'area di circa 240 km^2. Genova è tra le più importanti città Europee del Mar Mediterraneo ed è il più grande porto marittimo in Italia.

Il progetto PEARL interessa gli ultimi 5km del Bisagno, che è uno dei più problematici torrenti della regione per inondazioni (Faccini et al. 2016). Il torrente Bisagno è collocato in un'area con, a monte, una geomorfologia complessa e variazioni altimetriche, che sono la causa principale delle inondazioni nell'area urbana a valle. Il rischio di inondazione è inoltre aumentato dall'elevata urbanizzazione che negli anni ha considerevolmente modificato il corso naturale del torrente. Negli anni '30 gli ultimi 1,3km del corso d'acqua (dalla stazione Brignole alla Foce) sono stati tombati per recuperare spazio per edificare palazzi e strade. Questa copertura ha diminuito la portata nella parte terminale del torrente e aumentato di conseguenza l'incidenza di inondazioni nell'area urbana circostante. La combinazione tra la morfologia del bacino del Bisagno, le modificazioni antropiche all'area urbana e gli eventi idro-meteorologici che si generano localmente (precipitazioni intense, temporali V-shape) sono le principali cause di alluvioni lampo che hanno colpito la città negli anni. L'ultimo evento alluvionale a Genova si è verificato nell'Ottobre del 2014. Oltre a questo, altri eventi recenti sono stati nel 2010 e nel 2011. Dalla Seconda Guerra Mondiale eventi importanti si sono verificati nel 1951, 1953, 1970 e 1992 (Faccini et al. 2015). Tutti questi eventi hanno causato evacuazioni, talvolta perdita di vite umane ed ingenti danni economici.

Le alluvioni in area urbana rappresentano un grosso disagio per la città di Genova. Le strade sono interrotte, le persone non possono recarsi al lavoro o a scuola. Alcune zone pianeggianti restano allagate a lungo impedendo il transito dei veicoli. In zone della città in pendenza invece l'acqua ruscella ad alta velocità. Le strade fungono da rete di drenaggio ma il flusso non può entrare nei torrenti per via degli argini o altri ostacoli. Succede che la profondità dell'acqua non è elevata, ma la velocità del flusso impedisce alle persone di camminare in sicurezza. I danni economici sono ingenti. La propagazione e l'estensione delle alluvioni urbane a Genova è solitamente in funzione dell'intensità dell'evento, ma solitamente a causarle è un evento piovoso di media portata, che non necessariamente causa esondazione della rete di drenaggio naturale.

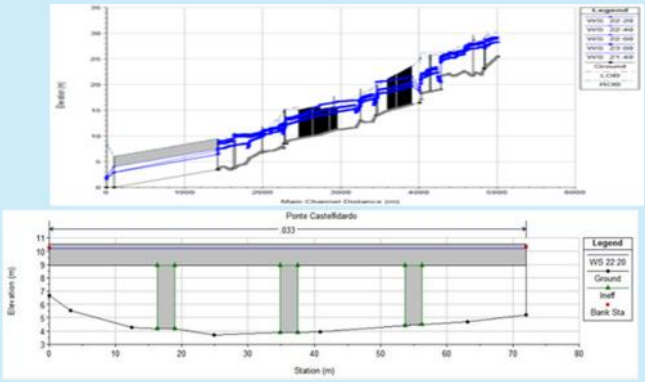
Il progetto PEARL vuole contribuire allo studio della generazione e degli impatti da eventi estremi, e valutare in maniera appropriata e secondo un approccio olistico, la vulnerabilità e il rischio nell'area del torrente Bisagno, per favorire una buona gestione e pianificazione e aumentare la resilienza da alluvioni da parte delle infrastrutture urbane e dei cittadini.

Bisagno Mouth/Foce del Bisagno

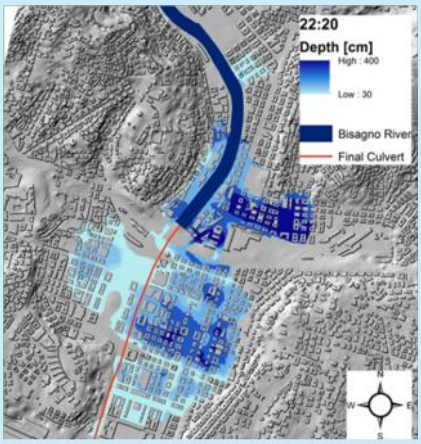
Flood 2014/Alluvione 2014

PEARL OUTCOMES

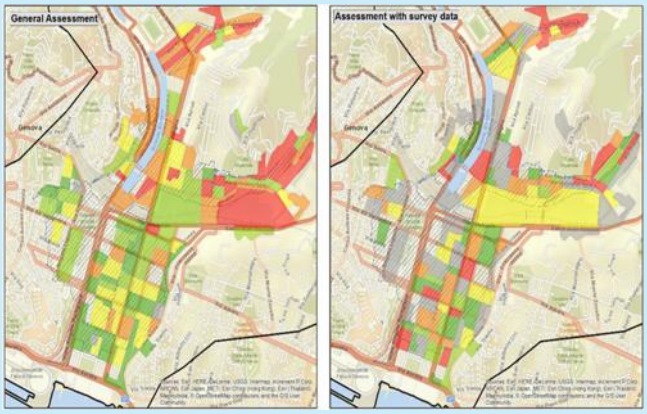
highlighting what needs to be done towards a more flood resilient city



Hydraulic Model/Modello idraulico



Flood mapby PEARL/Mappe inondazione PEARL



Vulnerability maps/Mappe vulnerabilità

Genoa case study carried out many activities and generated different outcomes, such as:

Flood/Hazard maps: a 1D hydraulic model (developed in HEC-RAS) and a 2D model (based on ArcGIS) for calculating water depths have been combined. Result is the generation of flood and hazards maps for two different rainfall events (2011 and 2014) and at a fixed time step.

Vulnerability Assessment: the PEARL vulnerability framework uses a robust index (called PeVI) to get a multifaceted picture of the current status of the societal component of vulnerability. PeVI is based on a modular structure with three elements: Susceptibility, Coping and Adaptation. However, it is adaptable and expandable to fit with local contexts and requirements. The assessment is primarily based on the secondary data available for social, environmental and economic indicators of vulnerability. The PeVI aims to cover as many aspects as possible in order to have a proper insight of the vulnerability of a city or a region under analysis.

Risk Assessment: The overall risk assessment consists in compound index based on the vulnerability assessment performed by the project partners IREUS (Stuttgart university) and UNESCO-IHE and the flood inundation maps generated by GISIG as project partners in the study area. For the purpose of this case study Risk is defined as:

Risk = Hazard x Vulnerability

In the case of the hazard component, two major flood events were used in this study: flood of 2011 and flood of 2014. For the event in 2011 the peak of the flood in terms of water depth was at 3:00 hours in the simulation and for the 2014 event the peak corresponds to the 22:20 hours. Having all the maps in raster format and reclassified into the 5 categories as for the vulnerability (lower, low, medium, high and higher) the next step in the risk computation was to multiply these maps. Due to the nature of the operation the output maps will range values between 0 and 25, where the lowest the number the less risk for that area in particular. An extra Reclassification of these maps was done to have a five category scale for risk and preserve the integrity with the other maps scale.

Flood Resilience Index: in PEARL, the resilience concept takes into consideration different aspects of the area, such as natural, physics, but also social, economic and institutional. The calculation has been done on the base of knowledge about the site and related flood events. Purpose of the FRI is to individuate specific contexts where the city government and management can be improved.

DESCRIZIONE DEL CASO DI STUDIO

Il caso studio Genova ha condotto diverse attività e generate differenti risultati, tra i quali:

Mappe di inondazione/pericolosità: i risultati del modello idraulico 1D (sviluppato in HEC-RAS) e del modello 2D (basato su ArcGIS) per calcolare la profondità dell'acqua sono stati combinati per generare mappe di inondazione e di pericolosità per due differenti eventi meteorologici (2011 e 2014) a intervalli temporali predefiniti.

Valutazione della vulnerabilità: la metodologia PEARL per il calcolo della vulnerabilità usa un indice (chiamato PeVI) per fotografare lo stato attuale della componente sociale della vulnerabilità. Il PeVi è basato su una struttura modulare con tre elementi: Suscettibilità, Capacità di far fronte alla situazione, Capacità di adottare strategie di adattamento. Inoltre, è adattabile a differenti contsti locali e necessità. La valutazione è basata principalmente su dati disponibili per il calcolo di indicatori di vulnerabilità dal punto di vista sociale, economico e ambientale. Il PeVI ambisce a coprire più aspetti possibili in modo da fornire un'idea della vulnerabilità della città o della regione in analisi.

Valutazione del Rischio: essa consiste in un indice composito basato sulla valutazione della vulnerabilità effettuata dai partner di progetto IREUS (Università di Stoccarda) e UNESCO-IHE e le mappe di inondazione generate da GISIG, partner responsabile del caso studio Genova. Per gli scopi del caso studio, il Rischio è definito come:

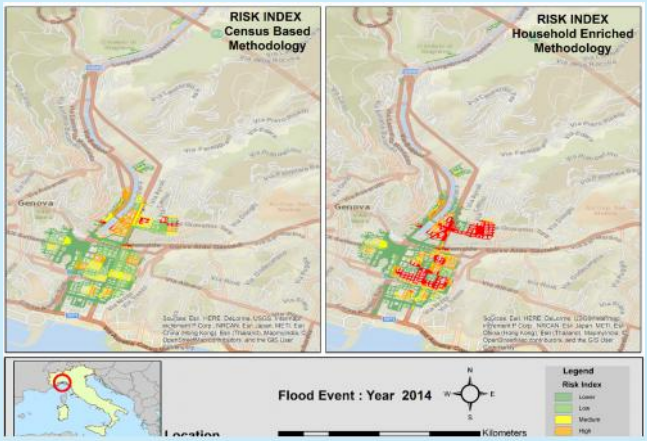
Rischio = Pericolosità x Vulnerabilità

Relativamente alla pericolosità, per questo studio sono stati usati due eventi principali: alluvione 2011 e alluvione 2014. Per l'evento 2011 il valore di picco, in termini di profondità dell'acqua, si è registrato nella modellazione intorno alle ore 3:00, mentre per il 2014 il valore di picco è stato alle 22:00. Tutte la mappe in formato raster e ri-classificate nelle 5 categorie (molto bassa, bassa, media, alta e molto alta) il passaggio successivo è stato il calcolo del rischio moltiplicando le mappe di pericolosità e vulnerabilità. L'operazione, per natura, ha fornito valori da 0 a 25, che sono stati a loro volta riclassificati nelle cinque categorie per garantire il confronto con le altre mappe.

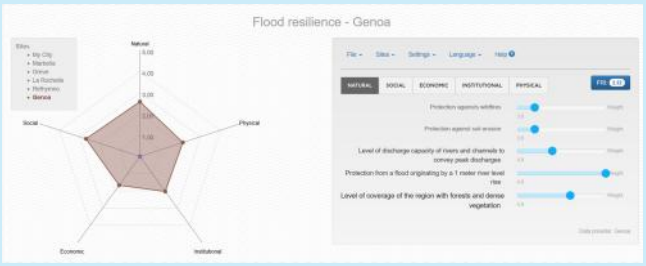
Indice di Resilienza alle Alluvioni (FRI): in PEARL, il concetto di resilienza prende in considerazione differenti aspetti dell'area, dal punto di vista naturale, fisico, ma anche sociale, economico e istituzionale. Il calcolo è stato fatto sulla base di conoscenze del sito e dei relativi eventi alluvionali. Scopo del FRI è di individuare contesti specifici entro i quali il governo e la gestione della città possono essere migliorati.

I RISULTATI DI PEARL

cosa deve essere fatto per avere una città più resiliente alle alluvioni



Risk maps/Mappe del rischio



Flood Resilience Index

THE ROLE OF LAAs, STAKEHOLDERS' & CITIZENS' PARTICIPATION

PEARL LAAs will bring together all stakeholders who are concerned with risks in the respective case study areas. This is a highly integrative and interdisciplinary task and thus this study aims at providing a comprehensive overview for all partners.

PEARL aims to an effective stakeholders' engagement in the process of development of risk management roadmaps for 7 case study areas from EU, taking into account the complexity of local decision processes, risk perceptions and the knowledge flows in order to identify the leverage points and appropriate scales/contexts, in which the project's support will produce an explicit impact.

In Genoa case study a LAA has been set including all key stakeholders and main actors involved in the emergency management, planning, monitoring and forecast of floods. Different workshops and meetings with stakeholders have been organized along the project, fostering collaboration and uptake of PEARL methodology and in particular the holistic and socio-economic approach.

Main involved stakeholders for Genoa pilot are:

- Municipality of Genoa, as the main PEARL stakeholder, it has been regularly updated about the project progress and also collaborated with GISIG to maximize the success of project activities and results. The Municipality of Genoa is the coordinator of the Climate Change Partnership of the Urban Agenda, where the PEARL uptake and follow-up is mostly encouraged.
- University of Genoa, Engineering and Earth Science departments. The University collaborated by providing students for the household survey, and actively participated in the LAA and in the scientific validation of the PEARL results. A lecture on PEARL holistic approach and socio-economic risk assessment has been held during the Applied Geomorphology course of the MsC in Geology.
- ARPAL, the hydro-meteorological center of Liguria Region that hosted PEARL partners for a site visit and was involved in different workshops and meetings.
- Fondazione CIMA, a Civil Protection research foundation, participated in the LAA also as local partner responsible for RISC KIT project, which was funded under the same programme of PEARL. It collaborated with GISIG by exchanging data, information and experiences.
- IREN Group, the multi-utility company of Genoa, was involved in LAA as stakeholder interested in the PEARL approach in view of drafting an intervention and emergency management plan for water resources management.
- Citizens in the flood prone areas, that collaborated with the household interviews and were as well informed about project aims.

La *Learning Actions Alliances* di PEARL mette insieme tutti gli stakeholders interessati alla gestione del rischio alluvionale nelle aree di studio. PEARL mira ad avere un elevato grado di coinvolgimento nel processo di sviluppo di una roadmap per la gestione del rischio in tutti i siti pilota di progetto, prendendo in considerazione la complessità dei processi decisionali locali, la percezione del rischio e il flusso di conoscenze utili a identificare la scala/contesto più appropriato nel quale il progetto possa apportare un impatto significativo.

Nel caso studio di Genova è stata implementata una LAA includendo tutti i portatori di interesse chiave e i principali attori coinvolti nella gestione delle emergenze, pianificazione, monitoraggio e previsione degli eventi alluvionali. Durante il progetto sono stati organizzati differenti workshops e meetings con gli stakeholders, per incoraggiare la collaborazione e l'acquisizione della metodologia PEARL, in particolare l'approccio olistico e socio-economico.

I principali stakeholders coinvolti nel pilota di Genova sono:

- Comune di Genova, è lo stakeholder principale di PEARL. Nel corso del progetto è stato regolarmente aggiornato sull'avanzamento delle attività ed ha anche collaborato con GISIG per massimizzare il successo delle attività stesse e dei risultati. Il Comune di Genova è il coordinatore della Partnership sui Climate Change in ambito Urban Agenda, nella quale l'utilizzo di PEARL è ampiamente incoraggiato.
- Università di Genova, Dipartimenti di Ingegneria Ambientale e Scienze della Terra. L'Università ha collaborato in PEARL attraverso gli studenti che hanno svolto le interviste porta a porta, e ha attivamente partecipato alla LAA e alla validazione scientifica dei risultati di progetto. Inoltre, di recente si è tenuta una a lezione sull'approccio olistico in PEARL e sulla valutazione del rischio alluvionale al corso di Geomorfologia Applicata della Laurea Magistrale in Geologia.
- ARPAL, centro meteo-idrologico della Regione Liguria, che ha ospitato i partner di PEARL per una visita, ed è stato coinvolto in differenti workshops e meetings.
- Fondazione CIMA, un centro di ricerca della Protezione Civile Nazionale, ha preso parte alla LAA anche in qualità di partner responsabile del siti locale del progetto RISC KIT, co-finanziato nell'ambito della stessa call di PEARL. Ha collaborato con GISIG nello scambio di dati, informazioni ed esperienze.
- Gruppo IREN, la società multi-utility di Genova, è stata coinvolta nella LAA come stakeholder interessato all'approccio di PEARL in vista di definire un piano di intervento e gestione delle emergenze per la gestione del ciclo idrico.

Cittadini delle aree a rischio alluvione, che hanno collaborato nell'ambito delle interviste porta a porta e sono stati informati circa gli scopi e i risultati di progetto.

IL RUOLO DELLE LAAs, LA PARTECIPAZIONE DI STAKEHOLDER & CITTADINI

ACTIVITY 1: Exploitation at institutional level

PEARL results and activities carried out in the Genoa pilot case are expected to be exploited at city and regional level, in order to foster the uptake of the holistic approach and related methodologies within the planning and management of floods and extreme events due to climate changes.

GISIG, as local PEARL partners, set an exploitation plan which is based on two main level of activities:

Activity 1: mainly addressed to exploit PEARL towards local and regional administrations and institutional contexts

Activity 2: mainly addressed to exploit PEARL in a training and academic context

At institutional level, the PEARL results exploitation is going to be carried out mainly in these directions:

- Exploitation of the PEARL results, tools and methodology in the Framework of the Climate Change Adaptation Partnership of the Urban Agenda, co-ordinated by the Municipality of Genova. The partnership started on July 2017 for three years, having the aim to draft and put into the practice an orientation plan on: (1) regulation; (2) knowledge; (3) funding for future climate change adaptation strategies.

- Promotion of Genoa as National Hub for Climate Change Adaptation, establishing a group of local and national stakeholders to address the National Climate Change Adaptation Plan (GISIG as expert in geo-spatial and Copernicus data).

- Promotion of PEARL results, such as the Floor Resilience Index (FRI), in the framework of other projects and initiatives on emergency management and urban planning, such as the project Anywhere, participated by the Genoa Municipality and CIMA Foundation and aimed at providing usable tools to respond more rapidly to extreme events.

- Promotion of new projects at city level, exploiting PEARL results, on socio-economic vulnerability and risk assessment, resilience, information to citizens.

ATTIVITA' 1:
Utilizzo a livello istituzionale

I risultati e le attività di PEARL condotte nel sito pilota di Genova è previsto vengano sfruttate a livello regionale e comunale, per favorire l'adozione di un approccio olistico e relative metodologie nell'ambito della pianificazione e della gestione di alluvioni ed eventi estremi da cambiamenti climatici.
GISIG, come partner locale di PEARL, ha messo a punto un piano per lo sfruttamento dei risultati di progetto che si basa su due tipologie di attività:
Attività 1: indirizzate principalmente a sfruttare PEARL a livello di amministrazioni locali e regionale e in contesti istituzionali.
Attività 2: indirizzate principalmente a sfruttare PEARL in un contest di formazione e accademico.

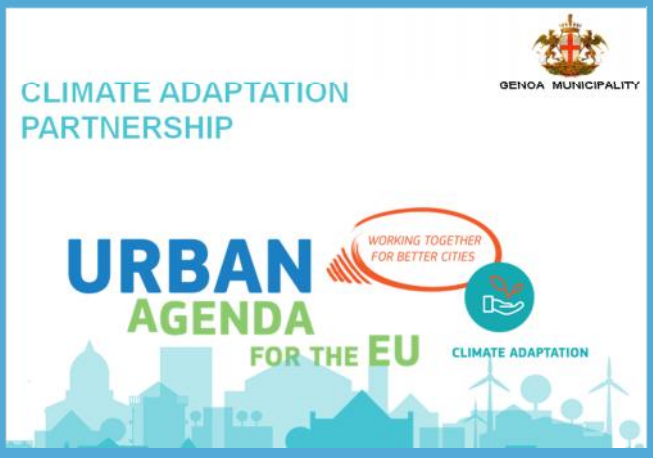
A livello istituzionale, le attività di sfruttamento dei risultati di PEARL intendono essere condotte principalmente in queste due direzioni:

- Sfruttamento dei risultati, degli strumenti e delle metodologie di PEARL, nell'ambito Climate Change Adaptation Partnership della Urban Agenda, della quale il Comune di Genova è coordinatore. La partnership è iniziata a Luglio 2017 per tre anni, allo scopo di definire e mettere in pratica un piano di orientamento su (1) legislazione; (2) conoscenza; (3) finanziamenti per le strategie future di adattamento ai cambiamenti climatici.

- Promozione di Genova come Hub nazionale per l'adattamento ai cambiamenti climatici, con l'istituzione dei un gruppo di stakeholder esperti locali e nazionali al fine di indirizzare il piano nazionale di adattamento(GISIG parteciperebbe come esperto in dati geo-spaziali e Copernicus).

- Promozione dei risultati di PEARL, tra cui il Flood Resilience Index (FRI), nell'ambito di altri progetti e iniziative sulla gestione delle emergenze e la pianificazione urbana, come ad esempio il porgetto Anywhere, partecipato dal Comune di Genova e dalla Fondazione CIMA e volto a fornire strumenti utilizzabili per fronteggiare con maggiore prontezza gli eventi estremi.

- Promozione di nuovi progetti a livello di città, per sfruttare i risultati di PEARL in pariticolare quelli relative alla valutazione della valutazione della vulnerabilità socio-economica e del rischio, alla resilienza e all'informazione al cittadino.



ACTIVITY 2: Exploitation at academic level

GISIG is looking for fostering the uptake of PEARL methodology and results also at academic and vocational training level, in order to push the new professional towards an holistic approach and a more integrated vision of the extreme events management, taking also into consideration the socio-economic aspects that can highly affect the vulnerability of an area.

Tangible actions have been already undertaken, whilst other are planned to be developed in the next months. Into the detail, the GISIG roadmap for this second activity consists of:

- Exploiting the PEARL vulnerability and risk assessment and the Flood Resilience Index methodology calculation in the framework of lectures carried out at academic level. Late in 2017, PEARL risk assessment and FRI methodologies have been explained by GISIG, also through practical exercises, in the framework of the Applied Geomorphology course of the Master of Science in Geology at the University of Genova. Holistic and socio-economic PEARL approach has been considered as complementary to the curricular topics, and important on the point of view of the vulnerability assessment and calculation.

- Exploiting the PEARL holistic approach and Genova vulnerability assessment into other research projects such as «Metro-Conflicts» developed by the University of Florence, as well as in scientific contexts with publications and papers.

Exploiting and further developing PEARL outcomes, methodologies and approach within the new project EO4GEO, coordinated by GISIG, aimed at skills development for supporting Copernicus uptake. PEARL in particular is expected to be exploited into the Climate Change training scenario, as well as within the organization of Copernicus Climathon, a 24-hours hackathon simultaneously organized in different cities of Europe and aimed at design projects for climate change adaptation. GISIG intends to organize a Copernicus Climathon in Genoa in October 2018.

ATTIVITA' 2:
Utilizzo a livello accademico

GISIG ambisce a favorire l'acquisizione della metodologia e dei risultati di PEARL anche a livello accademico e di formazione professionale, per fare si che i nuovi professionisti siano indirizzati verso un approccio olistico e una visione più integrata della gestione degli eventi estremi, prendendo inoltre in considerazione gli aspetti socio-economici che possono profondamente influenzare la vulnerabilità di un'area.

In questa direzione si sono già intraprese azioni concrete, mentre altre si stanno programmando nei prossimi mesi. Nel dettaglio, la roadmap di GISIG per questa seconda categoria di attività consiste in:

- Utilizzare le metodologie applicata in PEARL per la valutazione della vulnerabilità e del rischio e il calcolo del Flood Resilience Index come materiale di formazione a livello accademico. A fine 2017, la metodologia di valutazione del rischio in PEARL e il FRI sono stati spiegati da GISIG, anche attraverso un'esercitazione pratica, nell'ambito del corso di Geomorflologia Applicata della Laurea Magistrale in Scienze Geologiche dell'Università di Genova. L'approccio olistico e socio-economico di PEARL è stato considerate come complementare ai contenuti curriculari del corso, e importante dal punto di vista del calcolo e valutazione della vulnerabilità di un'area.

- Sfruttare l'esperienza dell'approccio olistico di PEARL e della valutazione della vulnerabilità in altri progetti di ricerca come ad esempio «Metro-Conflicts» condotto dall'Università di Firenze, così come in contesti scientifici con pubblicazioni e papers.

- Sfruttare e sviluppare i risultati di PEARL, le sue metodologie e il suo approccio nell'ambito del progetto EO4GEO, coordinato da GISIG e finalizzato a sviluppare competenze sull'utilizzo dei dati Copernicus. Ci si aspetta di sfruttare PEARL in particolare nello scenario di formazione sui cambiamenti climatici, così come nell'ambito del Copernicus Climathon, un hackathon di 24 ore organizzato contemporaneamente in vari paesi UE allo scopo di progettare soluzioni per l'adattamento ai cambiamenti climatici. GISIG intende organizzare un Climathon a Genova a Ottobre 2018.

LESSONS LEARNED, RESULTS & DISCUSSION

PEARL project brought to Genova a new concept for studying the flood events and their causes not only on the scientific point of view, but including also the socio-economic component.
The approach is well considered both at institutional and academic level, and the intention is to foster its application for improving the quality and the reliability of knowledge on the area.

The quantification of the flood vulnerability of an area is really important to plan interventions, to manage the emergency as well as to allocate funding also in terms of insurance products having prices consistent with the vulnerability and the risk of an area or building. Currently in Italy there is a big gap in insurance products against natural disasters, due to the lack of instruments to accurately assess the vulnerability of areas and properties.

Moreover, the experience developed in carrying out the interviews to 500 households within the flooded area of 2014 event, is really considerable and put the basis for a closer involvement of citizens in risk management. Similar approach has been used also in the project “Resilienza 141” as well as in the project “proterina3evolution” where interviews to citizens have been carried out to assess vulnerability of buildings as well as risk perception by inhabitants. It would be interesting and useful adopt this survey methodology in the whole city of Genova reaching as many inhabitants as possible to have a clear and comprehensive overview with a high level of detail.

CONCLUSIONI

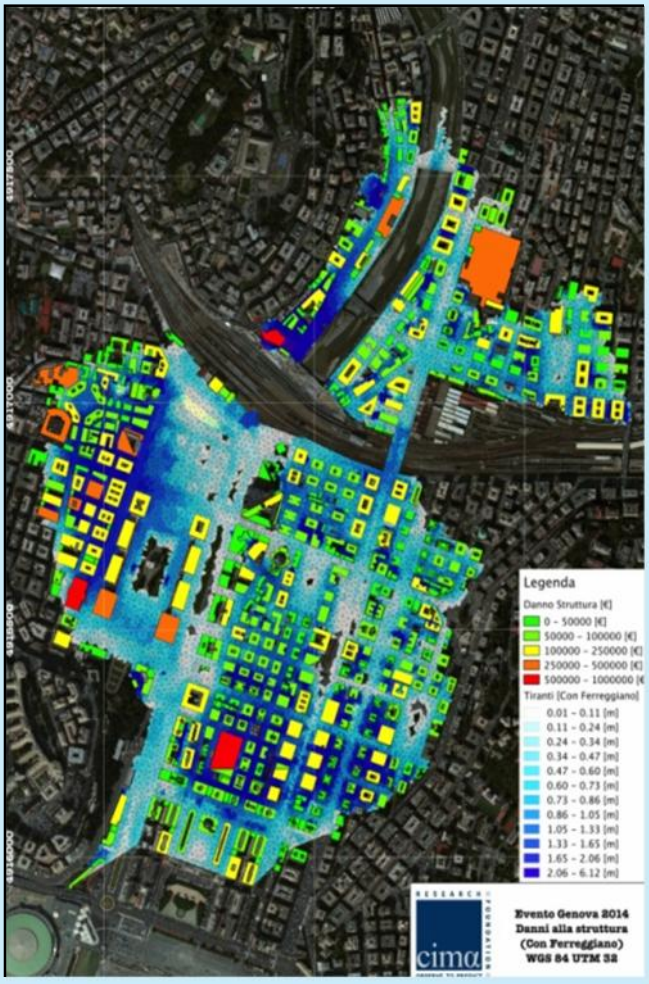
VALUTAZIONE DELL'ESPERIENZA, RISULTATI & DISCUSSIONE

Il progetto PEARL ha introdotto a Genova una nuova concezione di studio degli eventi alluvionali e delle problematiche ad essi connesse, che prende in considerazione non solo gli aspetti scientifici ma include anche la componente socio-economica.

L'approccio ha avuto molto riscontro sia a livello istituzionale che accademico, e l'intento è quello di incoraggiare la sua applicazione per migliorare la qualità e l'attendibilità delle conoscenze sull'area di studio.

La quantificazione della vulnerabilità alluvionale in un'area è molto importante ai fini della pianificazione degli interventi, per la gestione delle emergenze oltre che per allocare fondi. Importante è anche l'aspetto assicurativo e dei relativi prodotti, che devono avere premi calcolati sulla vulnerabilità e rischio reale di ogni singola zona o edificio. Attualmente in Italia c'è una grossa carenza di prodotti assicurativi contro i disastri naturali a causa della mancanza di strumenti adeguati per valutare la vulnerabilità di specifiche aree o proprietà.

Inoltre, l'esperienza sviluppata nello svolgimento delle interviste ai 500 nuclei familiari residenti nelle aree inondate dall'alluvione 2014 è veramente importante e mette le basi per un maggior coinvolgimento dei cittadini nella gestione del rischio. Un approccio simile è stato usato dal progetto "Resilienza 141"e dal progetto "proterina3evolution" in cui sono state condotte interviste ai cittadini di Genova per valutare la vulnerabilità degli edifici e la percezione del rischio da parte degli abitanti. Sarebbe interessante e utile applicare questa metodologia di indagine diretta su tutta la città di Genova raggiungendo più abitanti possibile per avere una chiara ed esaustiva visione di dettaglio.



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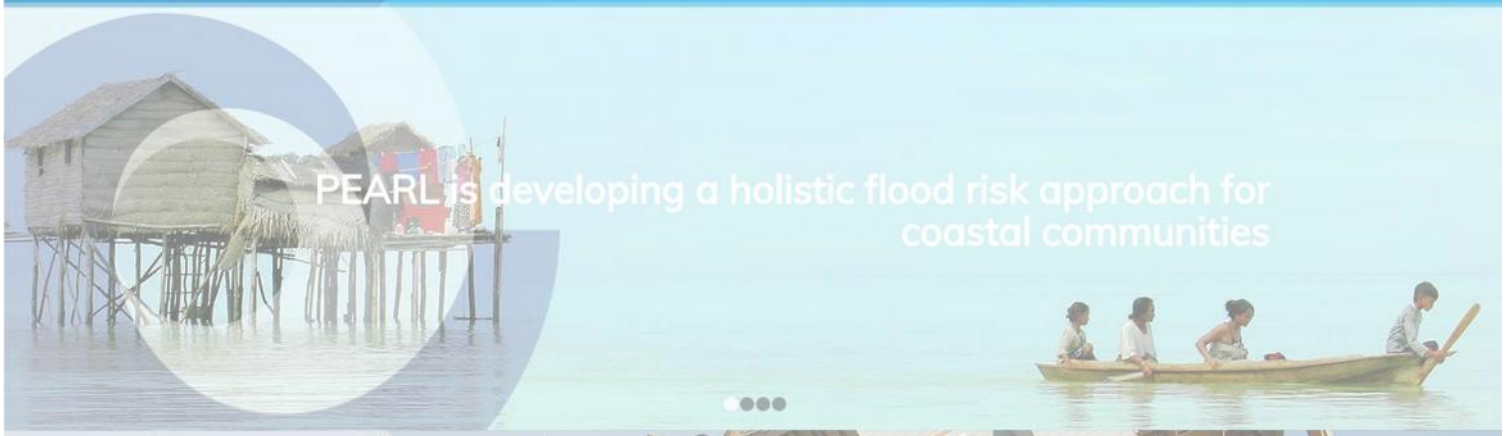
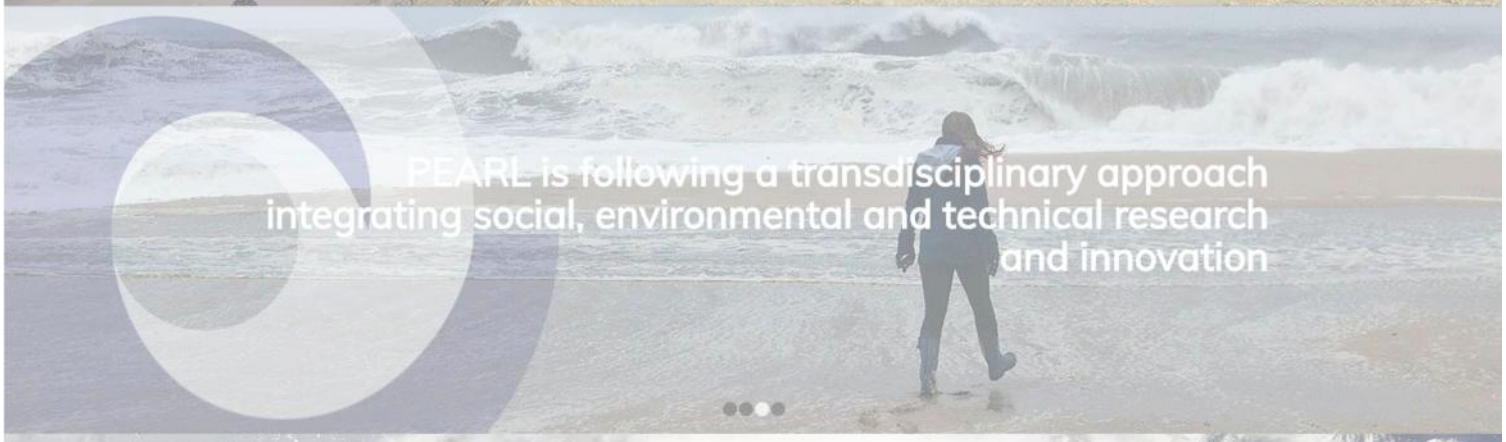
Preparing for Extreme And Rare events in coastaL regions

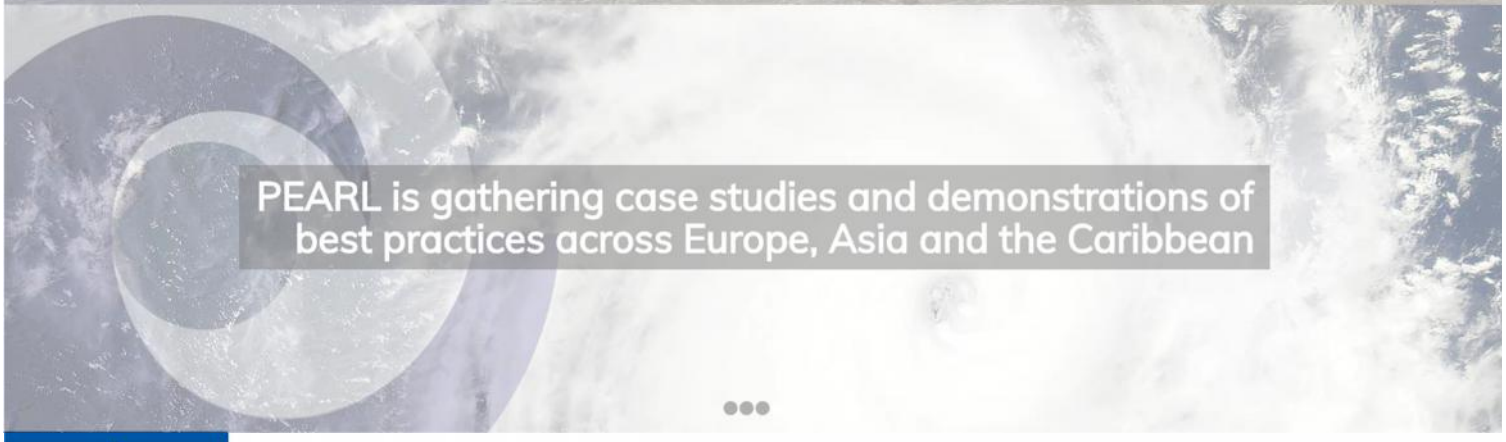


PEARL is developing a holistic flood risk approach for coastal communities

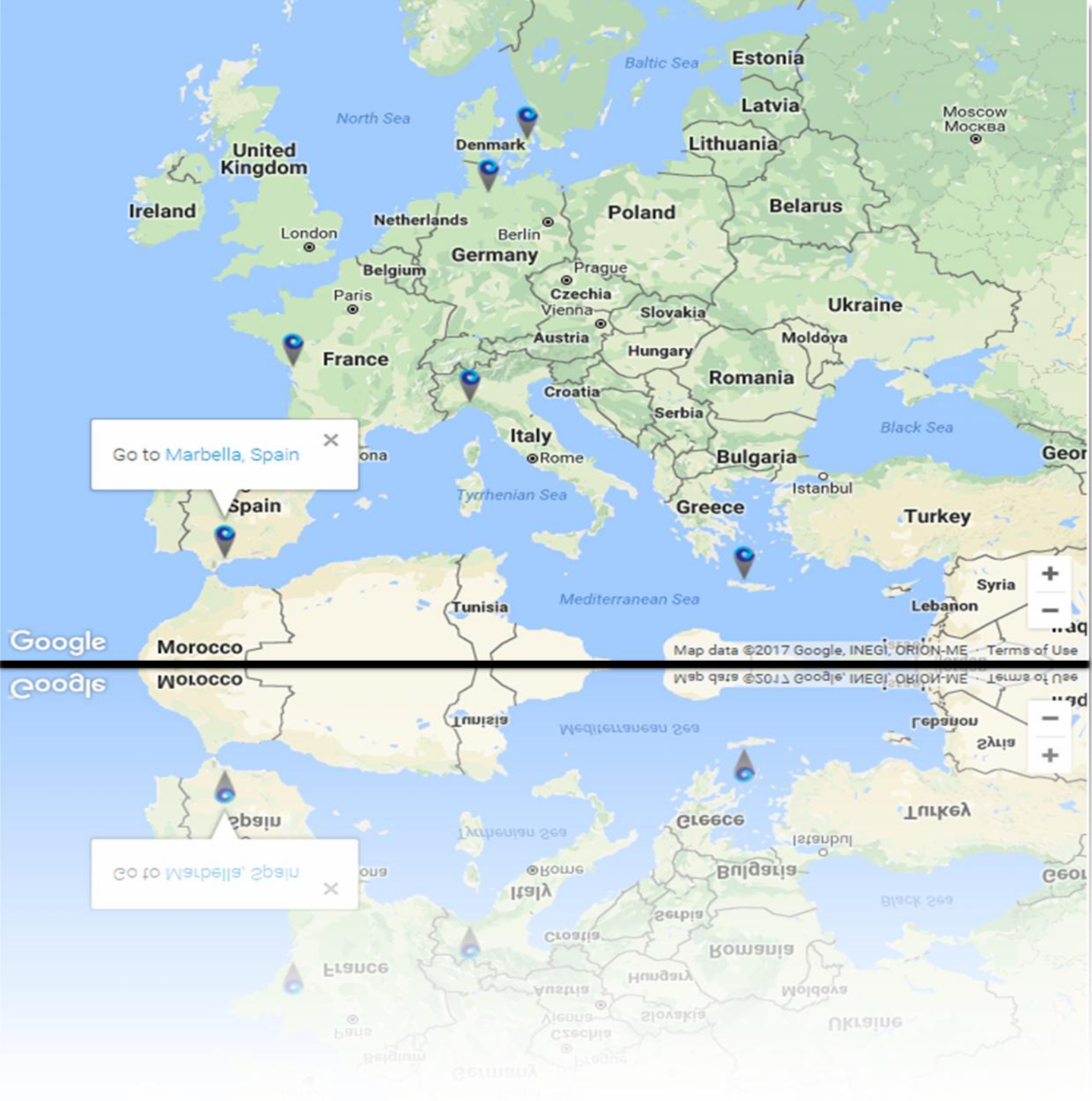
PEARL is improving forecasting, prediction and early warning capabilities



PEARL is following a transdisciplinary approach integrating social, environmental and technical research and innovation



PEARL is gathering case studies and demonstrations of best practices across Europe, Asia and the Caribbean



Risk Management Roadmap for the case study of Marbella, Spain

Centro Tecnológico del Agua, Fundación Privada

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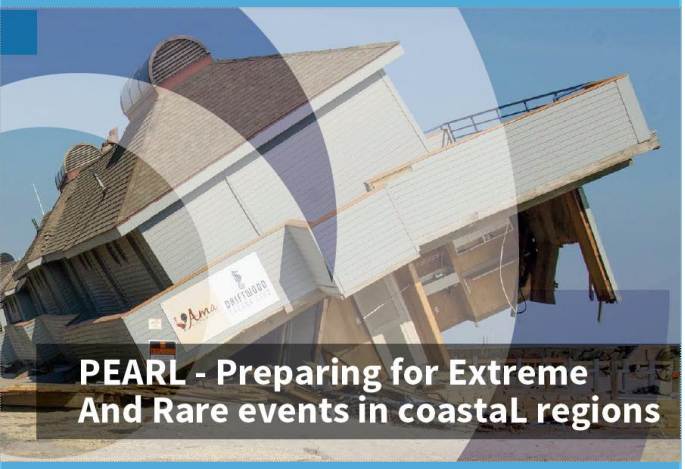
THE PEARL INITIATIVE

http://www.pearl-fp7.eu/

FLOOD RISK & FLOOD RISK MANAGEMENT



PEARL is a project aiming to develop adaptive risk management strategies for coastal communities against extreme hydro-meteorological events, minimising social, economic and environmental impacts and increasing the resilience of Coastal Regions in Europe.

PEARL's objectives are to:

- Develop a holistic risk governance framework
- Increase the understanding of dominant root causes of vulnerabilities and risks in coastal regions
- Improve the comprehension of the co-evolution of disasters due to extreme hydrometeorological events
- Develop new monitoring, modeling, forecasting and warning technologies tailored on the social, technical, institutional, organisational and economic realities of coastal communities
- Provide the means to strengthen risk governance and empower all stakeholders
- Build a pan-european knowledge to support capacity
- Development for the delivery of cost-effective risk-reduction plans

Expected outcomes:

1. Risk and Root Cause Assessment (RRCA)
2. Innovative flood modeling methodology
3. Holistic and multiple risk assessment framework
4. Early warning systems and technologies
5. Resilience strategies
6. Stakeholder Involvement
7. Science-policy interface and outreach

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LA INICIATIVA PEARL

http://www.pearl-fp7.eu/

PEARL es un proyecto con el objetivo de desarrollar estrategias de gestión para adaptarse al riesgo de comunidades costeras frente a eventos hidrometeorológicos extremos, minimizando impactos sociales, económicos y medioambientales e incrementando la resiliencia de regiones costeras en Europa.

- Los principales objetivos del proyecto PEARL son:
- Desarrollar un marco de gobernanza holístico del riesgo
- Incrementar el conocimiento de las causas fundamentales de vulnerabilidades y riesgos en regiones costeras
- Mejorar la comprensión de la co-evolución de desastres debidos a eventos hidrometeorológicos extremos
- Desarrollo de tecnologías de vigilancia, modelos de predicción y de alerta personalizadas para las realidades sociales, técnicas, institucionales, organizacionales y económicas de las comunidades costeras
- Proporcionar medios para fortalecer la gobernanza del riesgo y capacitar a todos los actores implicados
- Construir conocimiento paneuropeo de soporte
- Desarrollos de planes de reducción de riesgo efectivos

Resultados esperados:

1. Evaluación del riesgo y causas fundamentales
2. Metodologías innovadoras de modelización de inundaciones
3. Marco de evaluación holístico y múltiple
4. Sistema de alerta temprana
5. Estrategias de resiliencia
6. Participación de los diferentes actores
7. Acercamiento entre la política y la ciencia

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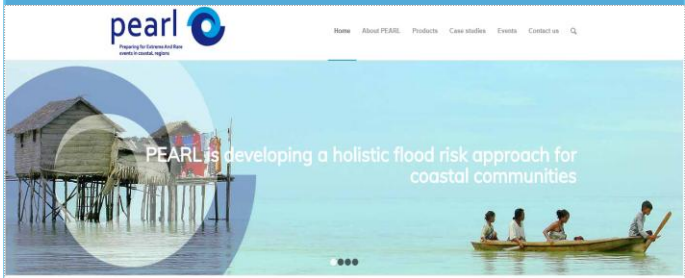
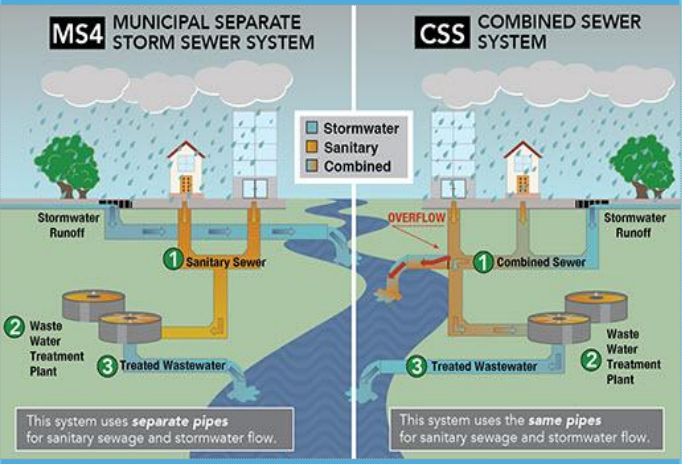
RIESGO DE INUNDACIÓN Y GESTIÓN DEL RIESGO DE INUNDACIÓN



THE PEARL PROJECT: Methods & Tools



PEARL activities are organised in eight Work Packages (WP). Several methods and tools have been developed within the first six Work Packages (WP) of the project:

WP 1 develops the PEARL Risk and Root Cause Assessment (RRCA) approach, whose aim is to provide a framework for analysing the underlying factors of risk and vulnerability in coastal regions, particularly for smaller (but more common) local events.

WP 2 intends to create a completely new methodology to analyse and model floods occurring from multiple sources, with the goal of supporting risk assessment for both long-term decisions as well as operational emergency/early warning planning.

WP 3 broadens the focus of traditional risk assessment through the adoption of a holistic view recognising interactions and interrelatedness between different processes. To this aim, it incorporates social aspects and the understanding of the vulnerabilities of various community groups.

WP 4 customises and establishes new methods for flood forecast and real-time data assimilation for early warning (especially for areas with combined flood risks), as well as uncertainty propagation and its impacts on decision making. Additionally, it seeks to improve both formal and informal dissemination of early warnings.

WP 5 builds a knowledge base of existing and new coastal flood management strategies and evaluation tools to later support policy-making and science-policy interfacing. The final goal is the development of an interactive web-based learning and planning platform to allow interaction with the key project products.

WP 6 enables the efficient management and conduction of data collection, scenarios development and results cross-linking in the case studies areas. Moreover, it evaluates the uptake of the PEARL methodology for holistic risk management and governance in coastal regions.

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EL PROYECTO PEARL:
Métodos y herramientas

Diferentes metodologías y herramientas se han desarrollado dentro de los seis primeros paquetes de trabajo (WP):

El **WP 1** desarrolla el enfoque para la evaluación del riesgo y de las causas fundamentales, con el propósito de ofrecer un marco para el análisis de los factores elementales del riesgo y la vulnerabilidad en regiones costeras, en particular para eventos locales más pequeños (pero más frecuentes).

El **WP 2** trata de crear una nueva metodología para analizar y modelizar inundaciones que ocurren debido a diferentes razones, con el propósito de ayudar a la gestión del riesgo para decisiones a tomar a largo plazo así como para la planificación de operaciones de emergencia y de alerta temprana.

El **WP 3** amplía la tradicional evaluación del riesgo mediante la adopción de un punto de vista holístico, reconociendo las interacciones e interrelaciones entre los diferentes procesos. Para conseguir esto, se incorporan aspectos sociales y el entendimiento de vulnerabilidades de varias asociaciones comunitarias.

El **WP 4** personaliza y establece nuevos métodos para la predicción de inundaciones y asimilación de datos en tiempo real para la alerta temprana (especialmente para áreas con riesgos combinados de inundaciones), así como la propagación de la incertidumbre y sus impactos en la toma de decisiones. Además, se busca la mejora de la difusión formal e informal de los resultados de la alerta temprana.

El **WP 5** construye una base de conocimiento de nuevas estrategias de gestión de inundaciones costeras y herramientas de evaluación para el soporte de la creación de políticas y de la interconexión entre ciencia y políticas. El objetivo final es el desarrollo de una plataforma web de aprendizaje y planificación para permitir la interacción entre los diferentes productos clave del proyecto.

El **WP 6** habilita la gestión eficiente y la conducción de la recopilación de datos, desarrollo de escenarios y resultados entrecruzados para los diferentes casos de estudio. Además, evalúa la aceptación de las metodologías del proyecto PEARL para la gestión holística del riesgo y la gobernanza en regiones costeras

PROBLEM DESCRIPTION, ISSUES & CHALLENGES

Marbella is a city that belongs to the province of Malaga and it is part of the “Costa del Sol”. It is located in the south of Spain, in the region called Andalucía. The city extends for 117 km^2 and (according to the Spanish Statistical Office in 2015) 138,679 habitants live there with a density of almost 1,200 hab/km^2.

The city is between a small mountain range and the sea. The case study is limited to the city centre where there is two main water streams, Represa channel and Huelo River. Marbella presents a typically Mediterranean topography with high slopes on the upper part of the basin and very flat areas close to the sea. As a Mediterranean city, it benefits with wet warm cool winter and ever drier hot summer, with a mean annual temperature of 18 °C.

The main challenges that have been identified in Marbella city are flash flood, storm surge and collapse of the sewer network due to the incapacity of the conduits. These events are characterized by high potential to create huge damages to people, assets and natural landscape.

The risk is even increased when flash flood and storm surge occur at the same time because, in this case, water runoff cannot be discharged into the sea. The main consequences are higher water depth and velocity values, so higher damages to assets and people. Climate change is expected to accentuate the risk. Some effects have been already identified, like the jellyfish bloom, which has been jeopardizing tourism in recent times.

Furthermore, Marbella conditions are further exacerbated because the economic activity of the city relies mainly on tourism, which is heavily affected and damaged by the extreme events that happen with a more and more high frequency in Marbella. Hazard and vulnerability increases imply that risk has been growing as well. Therefore, in order to manage the flooding risk, more tools have to be available for decision makers.

Thus, it is clear that this difficult situation needs measures to be solved and the risk analysis can be considered as a first important step towards the definition of a management strategy that includes efficient measures capable of reducing risk and extreme events frequency or, at least, their consequences on people.

RESUMEN DEL CASO DE ESTUDIO

Marbella es una ciudad que pertenece a la provincia de Málaga y forma parte de la Costa del Sol. Se encuentra localizada en el Sur de España, en la comunidad autónoma de Andalucía. Tiene una extensión de 117 km^2 y viven, según el Instituto Nacional de Estadística, 138,679 habitantes con una densidad de prácticamente 1,200 hab/km^2.

La ciudad se encuentra comprendida entre una pequeña zona montañosa y el mar. El caso de estudio se limita al centro de la ciudad por donde discurren dos cursos de agua principales, el arroyo de la Represa y el rio Huelo. Marbella presenta una topografía típica mediterránea, con altas pendientes en zona anta de la cuenca y zonas prácticamente planas en la parte más próxima al mar. Como ciudad mediterránea, disfruta de inviernos húmedos y templados y de veranos secos y cálidos, con temperaturas medias de 18 ºC.

Los principales desafíos que se han identificado en la ciudad de Marbella son las inundaciones repentinas, marejadas ciclónicas y entradas en carga de la red de alcantarillado debido a la falta de capacidad de los conductos. Estos eventos se caracterizan por su alta capacidad para producir daños tanto a personas y bienes como al paisaje natural.

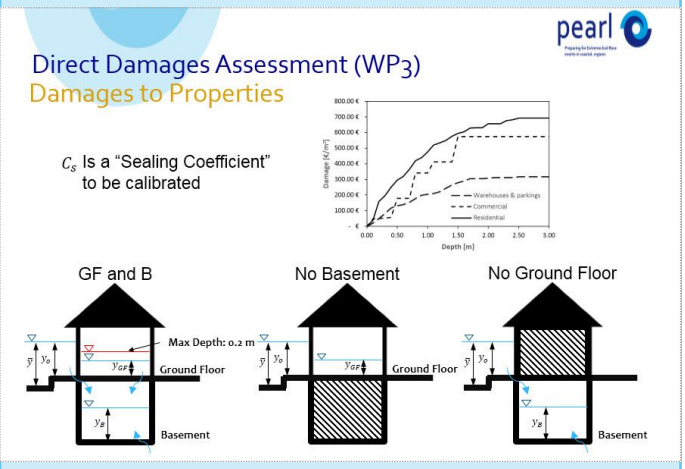
El riesgo se incrementa incluso más cuando las inundaciones repentinas y las marejadas ciclónicas se producen al mismo tiempo, puesto que el efecto combinado de ambos hace que las aguas drenadas no puedan ser vertidas al mar. Las principales consecuencias son altos calados y velocidades de agua, produciéndose así mayores daños a bienes y personas. Los efectos del cambio climático se espera que acentúen dichos riesgos. Algunos riesgos ya han sido identificados, como la proliferación de medusas que ha hecho peligrar la presencia de turistas en los últimos años.

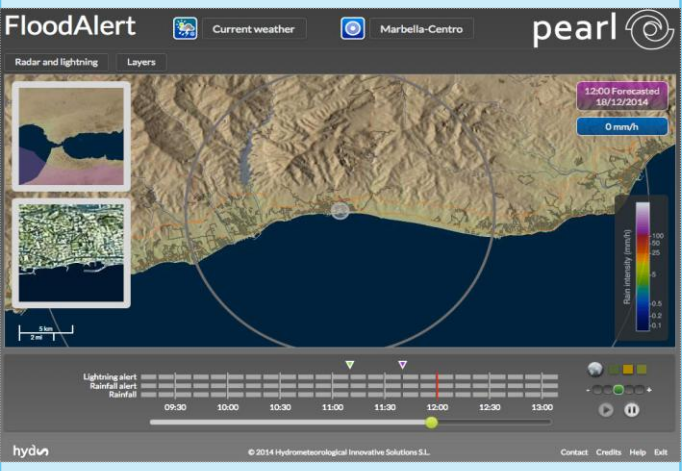
Además, puesto que el turismo es una de las actividades más importantes para Marbella, dichos riesgos agravan más la situación particular de esta ciudad. El hecho de que la peligrosidad y la vulnerabilidad incrementen, hace que también lo haga el riesgo. Por lo tanto, para gestionar el riesgo de inundaciones, se deben proporcionar más herramientas para la toma de decisiones. Así pues, dicha problemática requiere un análisis de los riesgos y una propuesta de medidas capaces de reducir tales riesgos ante los impactos de eventos extremos.

DESCRIPCIÓN DE LA PROBLEMÁTICA, SOLUCIONES Y DESAFÍOS

PEARL OUTCOMES

highlighting what needs to be done towards a more flood resilient city





This research allowed to have an overall view of the potential risk for pedestrians and damage provoked to properties and assets by flood events characterized by a set of design storms with several return periods. A risk and damage assessment has been conducted, focusing on pedestrians and buildings respectively.

The obtained result were necessary for the correct flood management in Marbella city due to old and recent flooding problems. The main consequences of typical heavy rainfall events in Marbella are that flooding can happen in a very short time and significant discharges are produced in few hours or minutes.

In the recent period, the damage has been increasing exponentially, therefore urgent measures have to be taken as soon as possible in order to avoid losses and to save economical resources which have been spent to recover previous conditions so far. Besides the hazard increase, Marbella has been also experiencing a raise of vulnerability because of the increasing urban population.

Forty groups of structural measures have been proposed, together with the non-structured measure of Early Warning System (EWM) developed, within the study area, which were classified into 5 levels of prioritization according to their impact over the operation of the sewer system. Among all the measures the main ones are related to repair bad conduits connections, increase of conduits hydraulic capacity, elimination of discharges, construction of new conduits and transformations from combined to separate sewers in certain places. The risks assessment when comparing 100 years return period flood in current and future state (with measures) indicates clearly how risks for pedestrians drops significantly, especially in Nabeul Avenue which is one of the most risky area currently. The damage assessment comparison denotes a high drop of the Expected Annual Damage (EAD) from 1,006,939.68 € to 97,767.24 € (91% of reduction), which means an adequate functioning of the proposed measures.

In this context, our research focuses on the need of new efficient and accurate tools. Risk and damage analysis represents a new way of thinking about flooding management because municipalities, companies, organizations and people are now able to have an overall view of the risks that threat their lives, properties and assets.

Con esta investigación se pudo obtener una visión general de los riesgos potenciales para peatones y del daño probable producido a las propiedades y bienes debido a eventos de inundación, a partir de simulaciones de lluvias de diseño para diferentes periodos de retorno. Se ha llevado a cabo una evaluación del riesgo y del daño para peatones y edificios respectivamente.

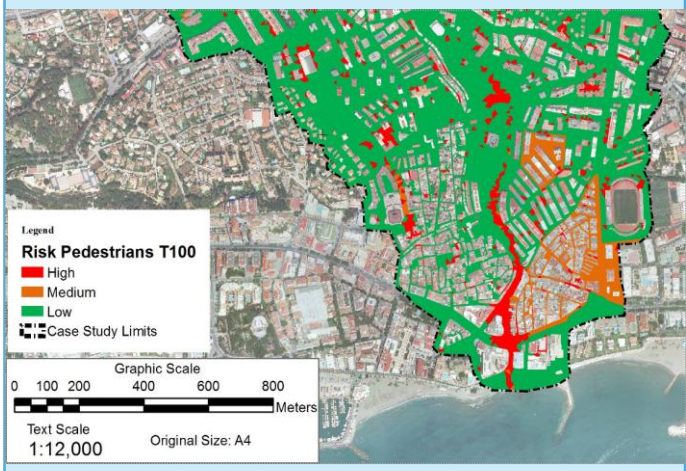
Los resultados obtenidos fueron necesarios para establecer una correcta gestión del riesgo de inundaciones en Marbella, debido a los eventos producidos en el pasado y en el presente. El principal problema en Marbella es que las típicas lluvias intensas producen inundaciones en un muy corto periodo de tiempo y con altos caudales circulando por las calles en pocas horas o incluso minutos.

EN los últimos tiempos, el daño producido ha crecido de una forma exponencial, por lo tanto se requieren medidas urgentes para evitar pérdidas y proteger recursos económicos. Además, la peligrosidad ha crecido en paralelo a la vulnerabilidad de la ciudad debido al aumento de la población.

Cuarenta grupos de medidas estructurales se han propuesto, junto con el desarrollo de un sistema de alerta temprana (SAT) (medida no estructural), dentro del área de estudio, y han sido clasificadas en cinco niveles de priorización según su impacto en el funcionamiento de sistema de alcantarillado. Entre todas las medidas, las principales tratan sobre la reparación de malas conexiones entre conductos, el aumento de capacidad hidráulica de conductos, eliminación de descargas, construcción de nuevos conductos y transformación de red unitaria a separativa en algunos lugares. La evaluación del riesgo se ha comparado para una inundación derivada de una lluvia de 100 años de periodo de retorno para la situación inicial y la situación en la que se consideran todas las medidas de mejora. Esta comparativa indica claramente como el riesgo para los peatones disminuye significativamente, especialmente en la avenida Nabeul, una de las zonas más afectadas por las inundaciones En cuanto a la evaluación de daños, dicha comparativa indica una caída en los daños, con una reducción del 91% en el indicador conocido como Daño Anual Esperado (DAE), de 1,006,939.68€ hasta 97,767.24€.

En este contexto, dicha investigación se centra en la necesidad de nuevas herramientas eficientes. El análisis del riesgo y del daño representa una nueva manera de entender la gestión del riesgo de inundaciones puesto que ayuntamientos, empresas, organizaciones y personas son ahora capaces de tener una visión general del riesgo que amenaza a peatones, bienes y propiedades.

RESULTADOS PEARL destacando qué debe hacerse para conseguir una ciudad más resiliente a las inundaciones



THE ROLE OF LAAs, STAKEHOLDERS' & CITIZENS' PARTICIPATION

Different stakeholders were involved in the Marbella LAA initiative: municipalities, public utility and private water companies, universities, consortium members, neighbourhood associations and representatives of public institutions related to the management of floods. They shared their experience to identify the difficulties caused by flood and exchanged different views.

The main dialogue with them was broken down into 4 main issues. Below the main conclusions are shown.

1. **Exposure and impact on the assets and population in a climate change context**
   a. Known flood-prone spots within the study area were highlighted by stakeholders in a map
   b. Lack of gutters and network cleaning
   c. Individual Flood-fighting structures are not used in Marbella
   d. Flash floods more frequent than before
   e. Urban planning is not taking into account the flood risks
2. **Post-flood event: returning to normality**
   a. Post-flood effects for flash floods last for days rather than weeks. Spatial scale is very local (convective storms)
   b. Businesses affected for 2-3 days to clean and restore
   c. There is no a clear pattern regarding insurance coverage. It depends a lot on the neighborhoods and on the property
   d. The insurance never cover the full damage
   e. Insurance companies make the bureaucracy quite fast and they usually pay in about a month after the event or reclamation
3. **Preparedness and early warning system in urban flooding**
   a. Early warning systems are not known by the civil population
   b. There is not enough knowledge or culture about flood risk among the population
   c. The current preventive cleanings to the network are not enough
   d. Some traffic disruptions exist in the most problematic spots
   e. Overall lack of information regarding what to do in flood emergencies
4. **Decision-making process and procedures in case of flooding**
   a. Citizens receive warnings through local media
   b. Improving education, risk perception and awareness-raising about floods is felt more important than improving warning systems
   c. Not enough information for tourists that are not aware of this issues

Diferentes actores participaron en la iniciativa LAA del proyecto PEARL para Marbella, entre los cuales se encontraban: ayuntamientos, servicios públicos y compañías de agua privadas, universidades, miembros del consorcio, asociaciones vecinales y representantes de instituciones públicas relacionadas con la gestión de inundaciones. Todos ellos compartieron su experiencia para identificar las problemáticas causadas por inundaciones así como el intercambio de diferentes puntos de vista.

Se trataron cuatro aspectos principales, siendo las conclusiones principales las descritas aquí:

1. **Exposición e impacto en bienes y población en un contexto de cambio climático**
   a. Se definieron los puntos críticos en cuanto a inundaciones señalándolos en un mapa
   b. Falta de rejas y de limpieza de la red de drenaje
   c. Las protecciones individuales para inundaciones no son usadas en Marbella
   d. Las inundaciones repentinas son más frecuentes hoy en día
   e. En la planificación urbana no se tienen en cuenta los riesgos de las inundaciones
2. **Post inundación: vuelta a normalidad**
   a. Los efectos post inundación ocasionados por inundaciones repentinas duran días más que semanas. La escala espacial es muy local (tormentas convectivas)
   b. Los comercios se ven afectados durante 2-3 días para tareas de restauración y limpieza
   c. No hay un claro patrón en cuanto a cobertura de seguros. Depende mucho del vecindario y de la propiedad en sí
   d. La aseguradora nunca cubre el daño total
   e. Las compañías de seguros realizan la burocracia bastante rápido y suelen pagar un mes después de que se produzca el daño
3. **Preparación y sistema de alerta temprana para inundaciones urbanas**
   a. La población civil no es conocedora de los sistemas de alerta temprana
   b. No hay cultura o conocimiento suficiente sobre la gestión del riesgo entre la población
   c. La actual limpieza preventiva de la red de alcantarillado no es suficiente
   d. Existe interrupción del tráfico en ciertos lugares
   e. Falta de información sobre qué hacer en caso de inundación
4. **Preparación y sistema de alerta temprana para inundaciones urbanas**
   a. Los ciudadanos reciben avisos a través de los medios locales
   b. Mejorar la educación, la percepción del riesgo y aumentar la concienciación sobre inundaciones se considera más importante que los sistemas de alerta
   c. No hay suficiente información para los turistas sobre estas problemáticas.

EL PAPEL DE LAS LAA, PARTICIPACIÓN DE GRUPOS DE INTERES Y CIUDADANOS

Martes, 12 Enero 2016 14:50

Ayuntamiento de Marbella, Cetaqua e Hidralia estudian planes antinundación

OBRAS Y SERVICIOS OPERATIVOS

Esta mañana se han presentado en el Palacio de Ferias y Congresos de Marbella las Jornadas Cetaqua-Hidralia, pertenecientes al proyecto europeo Pearl, en colaboración con UNESCO-IHE referente a inundaciones en áreas urbanas, donde se estudiará el caso práctico de la localidad de Marbella. A la jornada han asistido Blanca Fernández, Delegada de Obras e Infraestructuras del Ayuntamiento de Marbella, Xavier Aldea, responsable de proyectos de investigación en Cetaqua Centro Tecnológico del Agua y el gerente de Hidralia en Marbella, Carlos Corral.

Estas jornadas, que se desarrollarán los días 12, 13, 14 y 15 de enero en el Palacio de Congresos, tienen como fin reducir el impacto de las inundaciones urbanas en diferentes ciudades de Europa, a través de la generación de modelos que permitan calcular y medir las consecuencias de inundaciones futuras para el desarrollo de estrategias antinundación.

PARTIES INVOLVED

The current governance in Marbella aims to integrate flood risk management and urban planning in order to stop fighting against water and adapt to live with it. To get this objective it is necessary to create networks of stakeholders, engineers, professionals and decision makers who can cooperate, share interests and ideas, generate knowledge and results that allow to adapt the city of Marbella to the new climatic challenges.

The **Municipality of Marbella** is the main authority at local level. Their involvement is widespread, so all the PEARL issues are related to one or another area of the Municipality. Within their structure, the Department of Environment is the one dealing with some of the PEARL issues, specially focusing on the beaches and the receiving waters. On the other hand, all the issues related to the network and the operations depend of the Department of Civil Works.

The **Fire Department** of Marbella has an important role regarding flood emergency and recovery. The department depends of the Marbella Municipality. In addition to all the regular tasks that they do, they act when a flood occurs, as well as help to come back to the normal state of the city after the extreme event.

The **Civil Department** depends of the Municipality of Marbella. It is an organization mainly formed by volunteers that help disinterestedly when emergencies occur. Although there is a Civil Protection department that belongs to the Regional Government (Junta de Andalucía), the level of the issues that will be dealt in the Marbella case study mainly correspond to the local Civil Protection Department. The two of them work independently, being the Marbella one always reporting to the Municipality and not to the Junta.

Hidralia is the company managing the water distribution network and the sewage network in Marbella. The company (previously called Aquagest Andalucía) belongs to the SUEZ group, which is the same one to which CETaqua belongs. The water distribution contract started in 1992 and will last for 50 years. The management of the sewer network was granted on 2012, and will last 25 years. The first thing that was done within this contract, was the development of a Drainage Master Plan (DMP) and the acquisition of new equipment to clean and maintain the network. The instrumentation and modelling of the network were done in parallel with PEARL.

Although the whole city sewers are managed by Hidralia, the Waste Water Treatment plants and the interceptors are managed by the company **ACOSOL**. It is a public company that depends of the *Mancomunidad de Municipios de la Costa del Sol Occidental*, an association of the several coastal municipalities from the Costa del Sol area. Given that waste water treatment and the interception of the sewers belongs to them, collaboration with them is crucial to undertake a coordinated sewer management and minimise the water discharges to the sea.

La actual gobernanza en Marbella pretende integrar la gestión del riesgo de inundaciones y la panificación urbana para dejar de luchar contra el agua y adaptarse a vivir con ella. Para conseguir este objetivo es necesario crear redes de actores implicados, ingenieros, profesionales y aquellos que toman decisiones que puedan cooperar, compartir ideas e intereses, generar conocimiento y resultados que permitan la adaptación de la ciudad de Marbella a los nuevos desafíos climáticos.

El Ayuntamiento de Marbella es la autoridad principal a nivel local. Su implicación es extensa, de forma que todos los aspectos tratados por el proyecto PEARL están relacionadas con él. El Área de Medioambiente es la que trata principalmente los aspectos aquí analizados, principalmente las playas y aguas receptoras. Por otro lado, los aspectos relacionados con la red de alcantarillado y su operación dependen del departamento de obras e infraestructuras.

Los bomberos, que dependen del Ayuntamiento de Marbella, tienen un importante papel en relación a las emergencias por inundación para ayudar a recuperar la normalidad tras el evento.

La protección civil, es un departamento que también depende del Ayuntamiento. Se trata de una organización principalmente formada por voluntarios que ayudan de forma desinteresada cuando suceden emergencias. Aunque existe un departamento que pertenece al Gobierno Autonómico (Junta de Andalucía), el nivel de problemática tratado el proyecto PEARL requiere principalmente la intervención del departamento local de protección civil.

Hidralia es la empresa que gestiona la red de distribución de agua y alcantarillado en Marbella. La empresa (anteriormente llamada Aquagest Andalucía) pertenece al grupo SUEZ. La gestión de la red de alcantarillado es una concesión por 25 años y empezó en 2012. El primer trabajo realizado fue la redacción de un plan director de drenaje urbano, que propone las medidas que aquí se han descrito.

Aunque Hidralia gestiona el alcantarillado, las depuradoras y los interceptores son gestionados por la empresa ACOSOL. Es una empresa pública que depende de la Mancomunidad de Municipios de la Costa del Sol Occidental. Por lo tanto la colaboración con ellos es esencial para realizar una correcta gestión coordinada del alcantarillado y evitar al máximo las descargas al mar.

PARTES INVOLUCRADAS

Figures

ACTIVITY 1:
Awareness raising activities

More than 1,800 children of primary school from municipalities where Hidralia manages their water distribution and sewers, have participated in the education program Ambiental Aqualogía, with which it is aimed at teaching and increasing environmental values and the care of water.

Hidralia, who has been imparting this education program by the whole Andalusian geography, has brought Aqualogía during the first semester of the course 2016-2017 to the municipalities of Estepona, Manilva, Marbella and Benahavís (through Aguas de Benhavís).

Aqualogía presents water to scholars from a view according to their age. Thanks to multimedia programs, videos and appealing games the need of a responsible use and care of water, together with the care of the infrastructures that make water arrives to their houses and return it treated after use to the nature is highlighted.

The Aqualogía's objective is to educate children about the need of make a responsible use of drinking water as well as to manage the sewer network, by fostering environmental values such as treated water reuse.

On the other hand, Marbella City Council, Acosol and Hidralia have initiated an awareness campaign for the responsible use of wet wipes under the banner of "A simple gesture makes the difference. Use bins". The objective is improving the closer surroundings with actions which may seem to be small, but together represent a significant advance in the environmental issues.

Wet wipes are not biodegradable, though you may see they are indicated on the packaging, taking a lot of years until they decompose and provoking breakage, clogging and failures of the conduits, apart from major damages in pumping stations and waste water treatment plants. This is an issue that, besides to generating a cost for users and a malfunctioning of the service, it supposes a serious damage to the city environment

ACTIVIDAD 1:
Actividades de concienciación

Más de 1,800 niños de Educación Primaria de los municipios en los que Hidralia gestiona el Ciclo Integral del Agua han participado en el **Programa de Educación Ambiental Aqualogía**, con el que se pretende enseñar e incrementar los valores medioambientales y del cuidado del agua a los más pequeños.

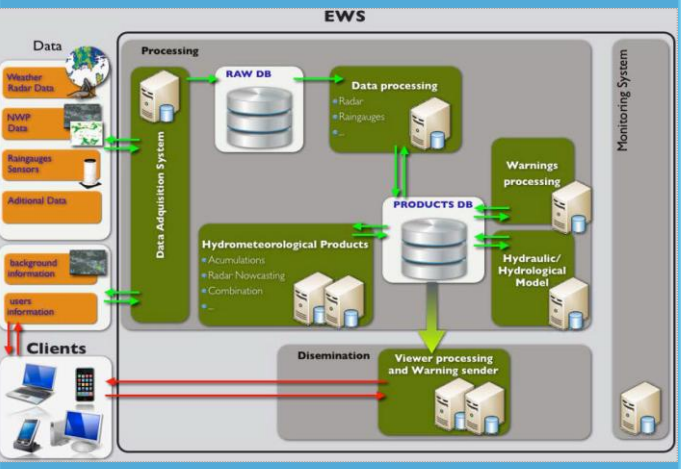
Hidralia, que lleva impartiendo este programa de educación por toda la geografía andaluza desde 2014, ha llevado Aqualogía durante el primer semestre del curso 2016-2017 a los municipios malagueños de Estepona, Manilva, Marbella y Benahavís (a través de Aguas de Benahavís). En total, unos 1,800 escolares de Primaria.

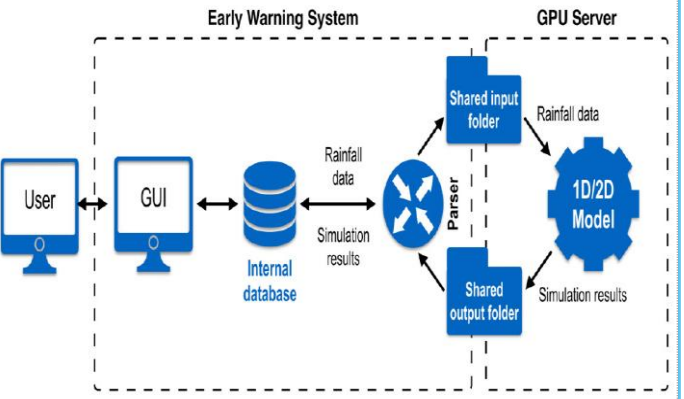
Aqualogía presenta el agua a los escolares desde una perspectiva acorde a su edad. Gracias a programas multimedia, vídeos y juegos atractivos se resalta la necesidad del buen uso y cuidado del agua y de las infraestructuras que hacen posible que este recurso llegue a sus casas y pueda devolverse a la naturaleza en las mejores condiciones posibles.

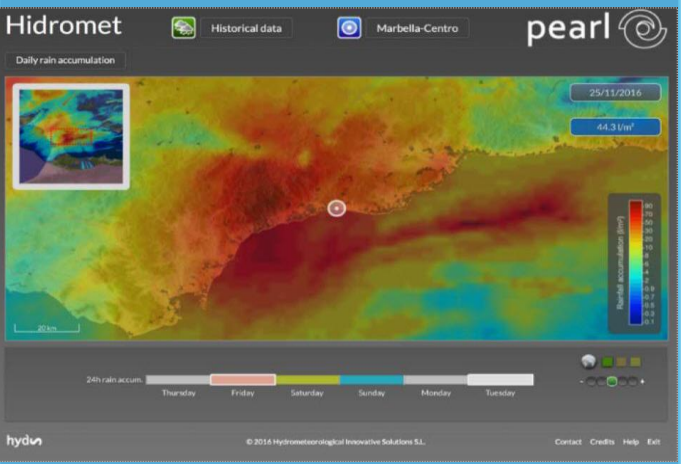
El objetivo de Aqualogía es concienciar a los niños y niñas sobre la necesidad de hacer un uso responsable tanto del agua potable como de la gestión del alcantarillado, al tiempo que se fomentan valores medioambientales como la reutilización del agua depurada.

Por otro lado el Ayuntamiento de Marbella, la empresa pública de aguas de la Mancomunidad de la Costa del Sol (Acosol) y la empresa Hidralia han puesto en marcha una **campaña de concienciación para el uso responsable de las toallitas higiénicas** bajo el lema “Un simple gesto marca la diferencia. Usa la papelera”. El objetivo es mejorar el entorno más cercano con actuaciones que, aunque parezcan pequeñas, representan en su conjunto un importante avance en esta materia medioambiental. Las toallitas no son biodegradables, aunque lo señalen en sus envases, tardando años en descomponerse y provocando averías, atascos y roturas en las tuberías, además de grandes daños en las estaciones de bombeo y depuradoras. Es un problema que además de generar un coste para los usuarios y un mal funcionamiento del servicio, supone un grave daño al medio ambiente de la ciudad.

ACTIVITY 2: Early Warning System (EWS)







Urban real time flood's Early Warning Systems (EWS) have been traditionally based on the use of rain gauges' observations to model the sewer network's behaviour by means of hydraulic models. A key issue in the EWS implemented in urban areas is the lead-time in detecting potential hazards. The Cloud system employed takes advantage of radar nowcasting techniques and software and hardware advances to feed a detailed hydrologic and hydraulic 1D/2D model (using GPUs), not only with observed precipitation by rain gauges, but also with forecasted precipitation for the following few hours. The warnings/information issued by the EWS can be spread through the viewer, email and SMS.

A flood EWS is based on different components. These components start from flood detection and forecasting to the timely, reliable and understandable disclosure of warning messages to authorities and population at risk.

The high temporal and spatial resolution of the radar observations, and the short-term forecast are valuable assets for urban flood EWS where response times are short.

Under the PEARL project framework (focused on The Represa catchment, Marbella), radar nowcasting and a numeric dual drainage model have been linked. The use of GPUs allows linking precipitation data with 1D/2D hydraulic modelling in real time.

The system developed is a Cloud system and can integrate the coupled model at two levels:

1. Link dynamically the real-time precipitation information and high-resolution pre-calculated maps.
2. Encapsulate the model in Cloud (using a dedicated server with a high-performance GPU) where it is run with updated observed or nowcasting data every time they are available. In this case, the model can generate hazard maps in real time for pedestrian that can be used for dissemination or warning protocol start up.

This tool is expected to be employed by the Marbella city council and Hidralia beyond the lifetime of PEARL project.

http://www.pearl-fp7.eu/

ACTIVIDAD 2: Sistema de Alerta Temprana (SAT)

Los sistemas de alerta temprana (SAT) de inundaciones urbanas en tiempo real, tradicionalmente se han basado en el uso de observaciones en pluviómetros para modelizar el comportamiento de la red de alcantarillado mediante modelos hidráulicos. Un aspecto esencial en los SAT implementados en zonas urbanas en tiempo requerido para detectar los peligros potenciales. El sistema en la nube empleado aprovecha las ventajas de las técnicas de radas de predicción a corto plazo y los avances en software y hardware para proporcionar la entrada de datos a un modelo hidráulico e hidrológico acoplado 1D/2D (usando GPUs), no solo con datos de lluvia observados de pluviómetros, sino también con predicción de la lluvia en las próximas horas. Los resultados de este sistema de alerta temprana (SAT) pueden ser mostrados en pantalla directamente o enviados al usuario mediante email o sms.

Un sistema de alerta temprana para inundaciones, se basa en diferentes componentes, desde la detección y predicción de la inundación hasta la comunicación entendible y puntual de mensajes de alerta a las autoridades y a la población en riesgo.

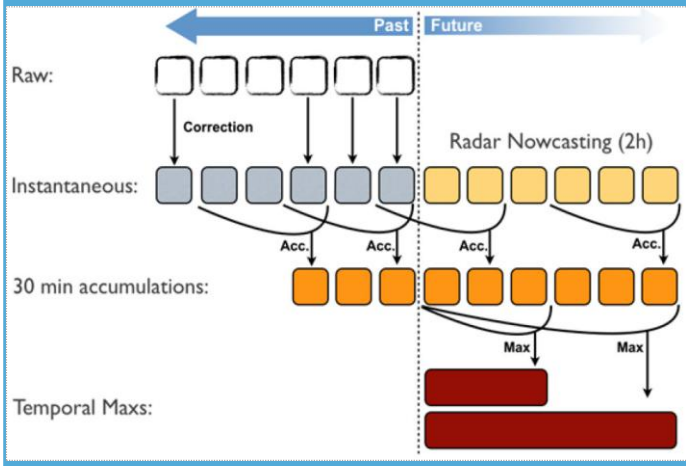
La alta resolución temporal y espacial de las observaciones de radar, y la predicción a corto plazo son aspectos esenciales cuando se trata de inundaciones urbanas en las que el tiempo de respuesta de cuenca es muy corto.

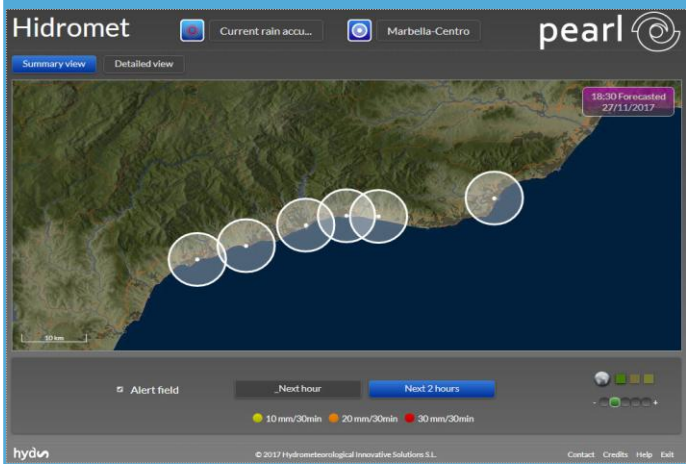
Bajo el marco del proyecto PEARL, centrado en la cuenca de la Represa (Marbella), se ha realizado el enlace de la predicción de lluvia de radar y el modelo numérico (hidráulico e hidrológico) de drenaje dual.

Los dos niveles desarrollados para el sistema en la nube que integran el modelo acoplado son los siguientes:

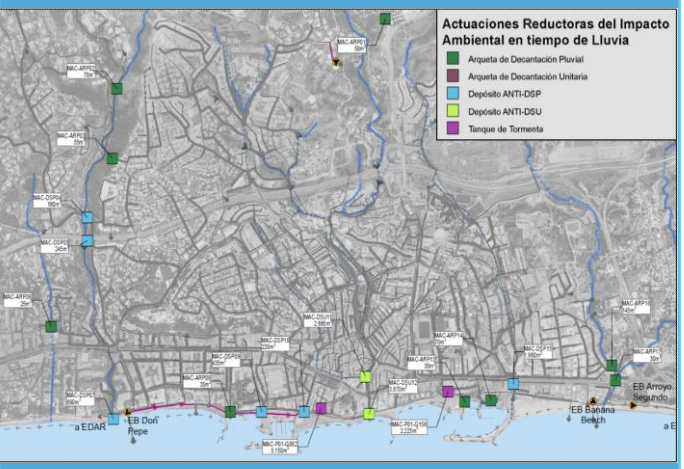
1. Enlace dinámico de la información de lluvia en tiempo real y los mapas de alta resolución pre-calculados.
2. Recoge el modelo en la nube (usando un servidor con alta capacidad de computación) donde calcula con datos observados o predichos cada vez que estén disponibles. En este caso, el modelo puede generar mapas de peligrosidad en tiempo real para peatones y puede ser utilizado como protocolo de difusión y alerta.

Se prevé que esta herramienta siga siendo utilizada por Hidralia y el propio Ayuntamiento de Marbella más allá de la vida del proyecto PEARL.





ACTIVITY 3: Implementation of structural measures



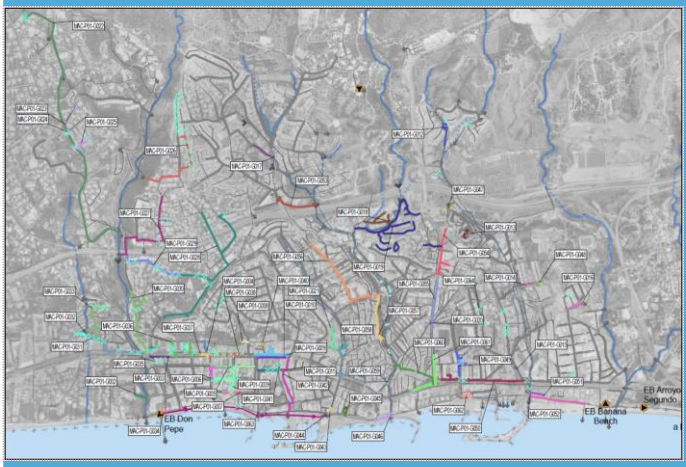
Forty groups of structural measures have been proposed within the study area that will be constructed within the next years. These were classified into 5 levels of prioritization according to their impact over the operation of the sewer system (P00, P01, P02, P03 and P04). Among all the measures the main ones are related to repair bad conduits connections, increase of conduits hydraulic capacity, elimination of discharges, construction of new conduits and transformations from combined to separate sewers in certain places. The total estimated budget for them is 15M€.

Prioritization	Problem to solve	Number
P00	Removal of wrong sewer connections to pluvial network and proper connection to the separate or combined sewer network.	21
	Removal of combined or separate sewer network that discharge to pluvial network and connection to existing or new sewer network for transportation to the wastewater treatment plant.	
P01	Actions against floods that eliminate hydraulic capacity problems of the existing sewer network for rainfalls of 1 year return period.	12
	Removal of connections of gutters to the sewer network and proper connection to combined or pluvial sewer network.	
P02	Actions against floods that eliminate hydraulic capacity problems of the existing sewer network for rainfalls of 2 year return period.	10
P03	Actions against floods that eliminate hydraulic capacity problems of the existing sewer network for rainfalls of 5 year return period.	9
P04	Actions against floods that eliminate hydraulic capacity problems of the existing sewer network for rainfalls of 10 year return period.	9

ACTIVIDAD 3: Aplicación de medidas estructurales

Se han propuesto cuarenta grupos de medidas estructurales para Marbella, que serán implementadas durante los próximos años. Se han clasificado en cinco niveles de priorización según su impacto sobre el funcionamiento del sistema de alcantarillado (P00, P01, P02, P03 and P04). Entre estas medidas las principales se centran en la reparación de conexiones a conducciones en mal estado, aumento de la capacidad hidráulica de conducciones, eliminación de vertidos, construcción de nuevos conductos y conversión de red unitaria a separativa en algunos lugares. El presupuesto estimado para estas medidas es de 15M€.

Priorización	Problema a resolver	Número
P00	Eliminación de conexiones de albañales a red separativa pluvial, y su conexión a red unitaria o separativa residual.	21
	Eliminación de los puntos de conexión de tramos de red unitaria o separativa residual que vierten a red separativa pluvial, y conexión a la red más idónea (existente o nueva), que permita transportar el agua residual a la depuradora.	
P01	Actuaciones anti-inundación que eliminan problemas de incapacidad hidráulica de la red existente frente a lluvias de periodo de retorno 1 año.	12
	Eliminación de conexiones de imbornales a red separativa residual, y su conexión a red unitaria o separativa pluvial.	
P02	Actuaciones anti-inundación que eliminan problemas de incapacidad hidráulica de la red existente frente a lluvias de periodo de retorno 2 años.	10
P03	Actuaciones anti-inundación que eliminan problemas de incapacidad hidráulica de la red existente frente a lluvias de periodo de retorno 5 años.	9
P04	Actuaciones anti-inundación que eliminan problemas de incapacidad hidráulica de la red existente frente a lluvias de periodo de retorno 10 años.	9



LESSONS LEARNED, RESULTS & DISCUSSION

Briefly, the present research activity allowed to have an overall view of the potential risk for pedestrians and damage provoked to properties and assets by flood events characterized by a set of design storms with several return periods. A risk and damage assessment has been conducted, focusing on pedestrians and buildings respectively.

The obtained result were necessary for the correct flood management in Marbella city due to old and recent flooding problems. The main consequences of typical heavy rainfall events in Marbella are that flooding can happen in a very short time and significant discharges are produced in few hours or minutes. Furthermore, in the recent period, the damage has been increasing exponentially, therefore urgent measures have to be taken as soon as possible in order to avoid losses and to save economical resources which have been spent to recover previous conditions so far. Besides the hazard increase, Marbella has been also experiencing a raise of vulnerability because of the increasing urban population.

Furthermore, Marbella conditions are further exacerbated because the economic activity of the city relies mainly on tourism, which is heavily affected and damaged by the extreme events that happen with a more and more high frequency in Marbella. Hazard and vulnerability increases imply that risk has been growing as well. Therefore, in order to manage the flooding risk, more tools have to be available for decision makers.

Thus, it is clear that this difficult situation needs measures to be solved and the risk analysis can be considered as a first important step towards the definition of a management strategy that includes efficient measures capable of reducing risk and extreme events frequency or, at least, their consequences on people.

Forty groups of structural measures have been proposed, together with the non-structured measure of Early Warning System (EWM) developed, within the study area, which were classified into 5 levels of prioritization according to their impact over the operation of the sewer system. Among all the measures the main ones are related to repair bad conduits connections, increase of conduits hydraulic capacity, elimination of discharges, construction of new conduits and transformations from combined to separate sewers in certain places. The risks assessment when comparing 100 years return period flood in current and future state (with measures) indicates clearly how risks for pedestrians drops significantly, especially in Nabeul Avenue which is one of the most risky area currently. The damage assessment comparison denotes a high drop of the Expected Annual Damage (EAD) from 1M€ to 98,000€ (91% of reduction), which means an adequate functioning of the proposed measures.

In this context, our research focuses on the need of new efficient and accurate tools. Risk and damage analysis represents a new way of thinking about flooding management because municipalities, companies, organizations and people are now able to have an overall view of the risks that threat their lives, properties and assets.

CONCLUSIONES

LECCIONES APRENDIDAS, RESULTADOS Y DISCUSIÓN

En resumen, el trabajo de investigación llevado a cabo ofrece una visión general de los posibles riesgos para peatones y daños producidos a edificios por inundaciones basadas en lluvias de diseño para diferentes periodos de retorno considerados. Se ha realizado una evaluación del riesgo y del daño centrándonos en los peatones y en los edificios respectivamente.

Los resultados obtenidos fueron necesarios para mejorar la gestión de inundaciones en Marbella, dados los problemas de inundaciones antiguas y más recientes. Las consecuencias principales de lluvias intensas en Marbella son las inundaciones que se producen en un breve periodo de tiempo, horas e incluso minutos. Además, recientemente, el daño ha crecido de forma exponencial, con lo que se requieren medidas de forma urgente para evitar tales daños y volver a la situación previa a la inundación lo más rápido posible. La peligrosidad también ha incrementado, junto con el aumento de la vulnerabilidad derivado del incremento de la población urbana.

La situación de Marbella de agrava al tener en cuenta que su principal actividad económica recae sobre el turismo, que se ve fuertemente afectado por estos eventos extremos cada vez más frecuentes en Marbella. Para gestionar ese incremento del riesgo, derivado del aumento de la peligrosidad (inundaciones) y la vulnerabilidad (población), se requieren más herramientas que permitan la toma de decisiones.

Resulta clara, por tanto, la necesidad de medidas para esta difícil situación, siendo el análisis del riesgo el primer paso, hacia una mejora de la estrategia de gestión de inundaciones.

Se han propuesto cuarenta grupos de medidas estructurales, clasificados en cinco niveles de priorización según su impacto sobre el funcionamiento del sistema de alcantarillado (P00, P01, P02, P03 y P04), junto con el desarrollo de un sistema de alerta temprana (SAT) como medida no estructural. Entre estas medidas estructurales las principales se centran en la reparación de conexiones a conducciones en mal estado, aumento de la capacidad hidráulica de conducciones, eliminación de vertidos, construcción de nuevos conductos y conversión de red unitaria a separativa en algunos lugares. La evaluación del riesgo al comparar una inundación de 100 años de periodo de retorno, para una situación inicial y una futura (con la aplicación de todas las medidas) indica claramente como el riesgo para estabilidad de peatones disminuye significativamente y el impacto económico se reduce en un 91%.

En este contexto, nuestra investigación se centra en la necesidad de proporcionar herramientas útiles y eficientes. El análisis del riesgo y de la peligrosidad representa un nuevo concepto en la gestión de las inundaciones puesto que ayuntamientos, empresas, organizaciones y ciudadanos son capaces de tener una visión general de los riesgos que les amenazan, y los daños potenciales a los que sus bienes están expuestos.

Lecciones aprendidas

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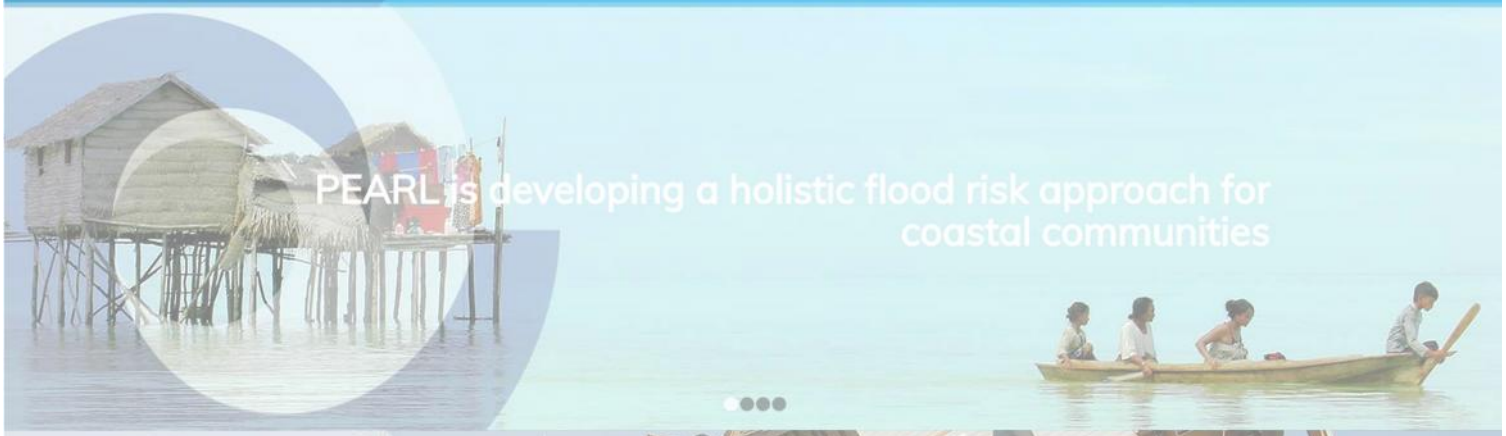
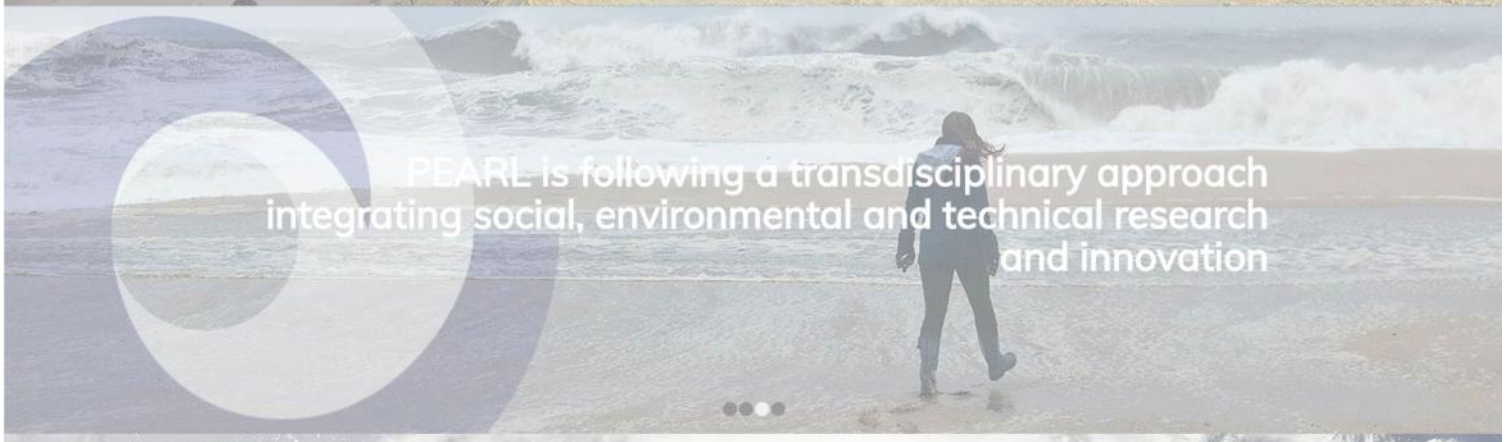
Preparing for Extreme And Rare events in coastaL regions

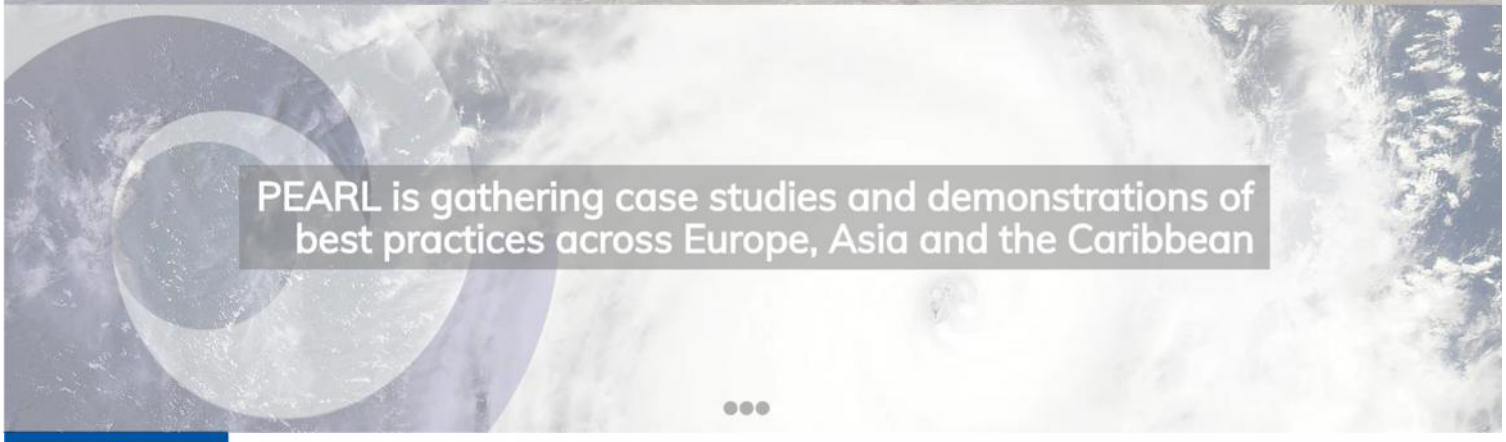


PEARL is developing a holistic flood risk approach for coastal communities

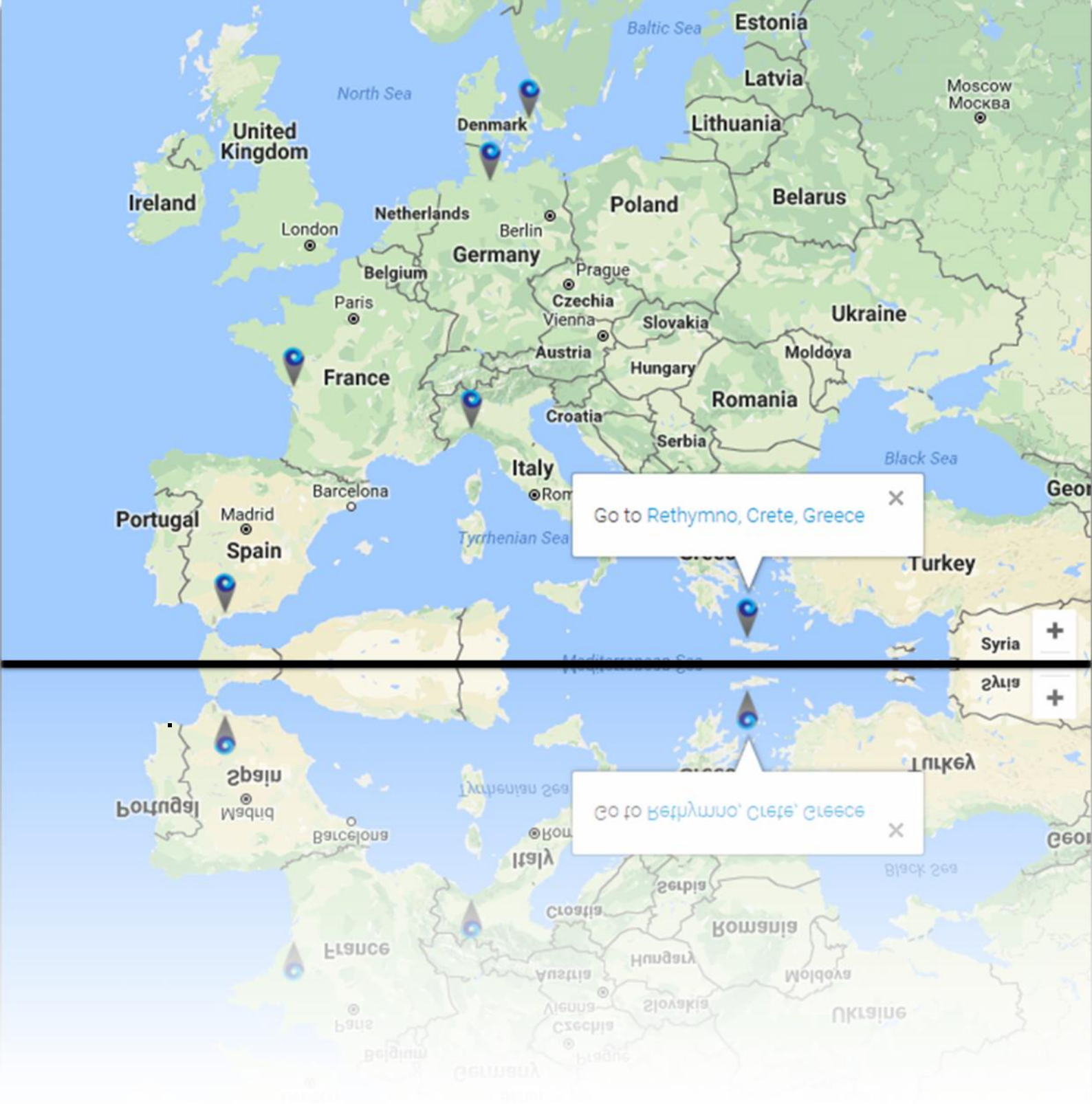
PEARL is improving forecasting, prediction and early warning capabilities



PEARL is following a transdisciplinary approach integrating social, environmental and technical research and innovation



PEARL is gathering case studies and demonstrations of best practices across Europe, Asia and the Caribbean



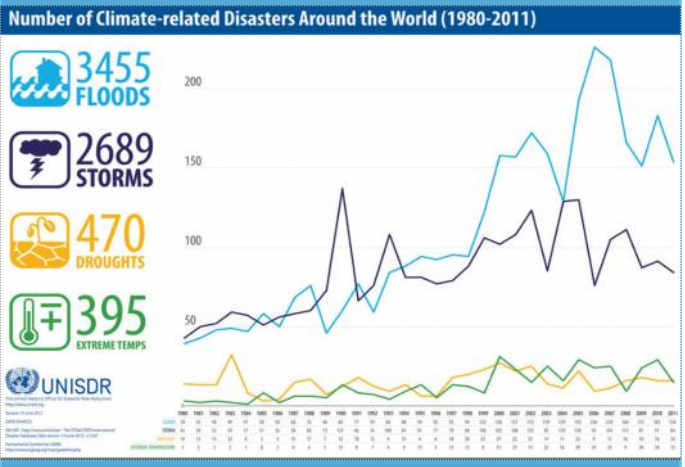
Risk Management Roadmap for the case study of Rethymno, Crete, Greece

National Technical University of Athens
Εθνικό Μετσόβιο Πολυτεχνείο

pearl
Preparing for Extreme And Rare events in coastaL regions

FLOOD RISK & FLOOD RISK MANAGEMENT

Flooding & Impact/ Πλημμύρες & Επιπτώσεις



Statistics / Στατιστικά

Flood Types / Τύποι Πλημμύρας

Coastal floods are regarded as one of the most dangerous and harmful of natural disasters. Rapid urbanisation in coastal areas combined with climate change and poor governance can lead to a significant increase in the risk of local pluvial flooding. When this coincides with high water levels in rivers and high tide or storm surges from the sea, an even greater risk of devastation may affect coastal communities.

To cope with this increased risk, there is a need to improve forecasting and prediction using state of art science and technology to help policy makers and emergency services to develop robust risk reduction strategies. However, forecasting and prediction is only part of the answer. Of equal importance is the ability to effectively warn the population in areas that will be affected, and that early warning systems for the general public are integrated into broader management strategies and supported by appropriate institutional and organisational arrangements. Preparing for effective response to extreme events not only involves technology but also significantly social, economic, organisational and political considerations.

Flood risk management aims to reduce the likelihood and/or the impact of floods. Experience has shown that the most effective approach is through the development of flood risk management programmes incorporating the elements of prevention, protection, preparedness, emergency response, recovery and lessons learned. Reducing human casualties and damage to economic activity and the environment are key objectives shared by all EU countries and implementation of the 2007 Floods Directive has an important role in making this happen.

The Directive applies to all kinds of floods (river, lakes, flash floods, urban floods, coastal floods, including storm surges and tsunamis) and it is being implemented in a three-base process i.e. the preliminary flood risk assessment, the development of floods hazard and flood risk maps and eventually the production of flood risk management plans. River Basin Districts are the main units for the management of river basins, as described within the Water Framework Directive, therefore, they were adopted for the EU Flood Directive too.

Flood maps are being used by many different stakeholders within flood risk management and serve purposes related to prevention of new risk build-up, reduction of existing risks and adaptation to changing risk factors. Development and use of flood maps serve multiple purposes such as conduction of flood risk management plans, land use planning and land management, emergency planning, public awareness raising and within the private sector e.g. insurance assessment and pricing.

Floods, among others, are commonly referred to as natural disasters but they are not in fact the results of nature-related processes alone. They are to an ever-increasing extent directly attributable to various social, economic, historical, political and even cultural issues. The perception of flood impact on life and daily activities can be significantly different amongst the population and the level of knowledge and understanding of flood risk in a given area is directly related to people's decisions to either adjust their living to such a risk or simply ignore it.

The PEARL project sought to fill in the lack of interaction between social aspects and technical measures – appearing to be a major hindrance for solving some of the greatest problems associated with floods and flood-related disasters.

Οι παράκτιες πλημμύρες θεωρούνται ως μία από τις πιο απειλητικές φυσικές καταστροφές. Η ταχεία και έντονη αστικοποίηση στις παράκτιες περιοχές συνδυασμένη με την κλιματική αλλαγή και την ελλιπή διακυβέρνηση μπορεί να οδηγήσει σε σημαντική αύξηση του κινδύνου πλημμυρών από έντονη βροχόπτωση, με παράλληλη αύξηση στάθμης ύδατος σε ποτάμια ή τη θάλασσα (λόγω κυμάτων θύελλας ή παλίρροιας), θέτοντας σε ακόμα μεγαλύτερο κίνδυνο καταστροφής της παράκτιες κοινωνίες.

Η ανάγκη βελτίωσης της πρόγνωσης/πρόβλεψης και των συστημάτων έγκαιρης προειδοποίησης αξιοποιώντας καινοτόμες λύσεις της επιστήμης και της τεχνολογίας, θα βοηθήσει τους φορείς χάραξης πολιτικών και τις υπηρεσίες έκτακτης ανάγκης, να αναπτύξουν ισχυρές στρατηγικές μείωσης των κινδύνων. Παρόλα αυτά, η πρόγνωση/πρόβλεψη αποτελεί μέρος μόνο της λύσης. Ίσης σημασίας είναι και η δυνατότητα αποτελεσματικής προειδοποίησης του πληθυσμού που πρόκειται να επηρεαστεί από ένα γεγονός, πράξη η οποία μάλιστα πρέπει να ενσωματώνεται σε ευρύτερες στρατηγικές διαχείρισης και να υποστηρίζεται από κατάλληλες θεσμικές και οργανωτικές ρυθμίσεις. Η προετοιμασία για την αποτελεσματική αντιμετώπιση των ακραίων γεγονότων δεν περιλαμβάνει μόνο τις τεχνολογικές λύσεις, αλλά και σημαντικά κοινωνικά, οικονομικά, οργανωτικά και πολιτικά ζητήματα.

Η διαχείριση του κινδύνου των πλημμυρών στοχεύει στη μείωση της πιθανότητας εμφάνισης ή/και της επίπτωσής τους. Η εμπειρία έχει αναδείξει ότι πιο αποτελεσματική προσέγγιση είναι εκείνη η οποία λαμβάνει υπόψη τα στάδια πρόληψης, προστασίας, ετοιμότητας, άμεσης απόκρισης, αποκατάστασης και εξαγωγής διδαγμάτων. Μείωση των ανθρώπινων απωλειών και ζημιών οικονομικής φύσης και του περιβάλλοντος αποτελούν καίρια σημεία της Οδηγίας για τις Πλημμύρες (2007/60/ΕΚ).

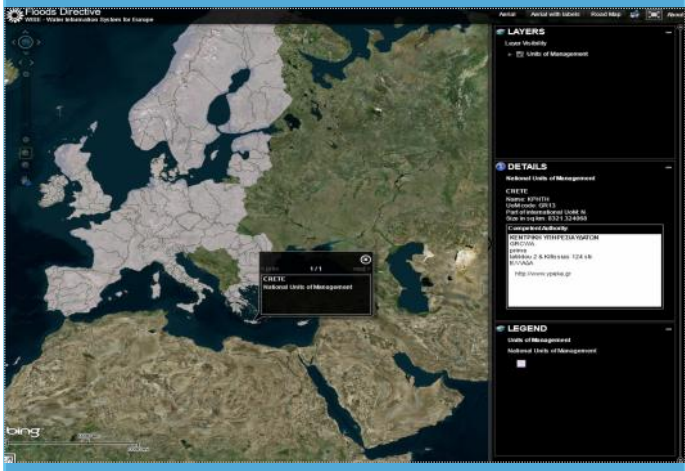
Η Οδηγία αφορά όλους του τύπους πλημμύρας και εφαρμόζεται σε 3 στάδια, την προκαταρκτική αξιολόγηση, την παραγωγή χαρτών κινδύνου και επικινδυνότητας και τελικά την κατάρτιση Σχεδίων Διαχείρισης Κινδύνων Πλημμύρας. Τα υδατικά διαμερίσματα αποτελούν χωρική μονάδα εφαρμογής της, σε αντιστοιχία με την Οδηγία Πλαίσιο για τα Νερά.

Οι παραγόμενοι χάρτες αξιοποιούνται από διαφορετικούς φορείς και εξυπηρετούν πολλαπλούς σκοπούς όπως πρόληψη δημιουργίας νέων κινδύνων, μείωση εμφάνισης υφιστάμενων και προσαρμογή στις μεταβαλλόμενες συνθήκες. Συγκεκριμένα παραδείγματα χρήσης τους είναι η κατάστρωσης σχεδίων διαχείρισης κινδύνου, ο αστικός σχεδιασμός, η διαμόρφωση σχεδίων έκτακτης ανάγκης, η ευαισθητοποίηση του κοινού αλλά και οι διαδικασίες ασφάλισης και αποτίμησης κόστους.

Οι πλημμύρες μπορεί να χαρακτηρίζονται ως φυσικές καταστροφές αλλά επηρεάζονται άμεσα από διάφορα κοινωνικά, οικονομικά, ιστορικά, πολιτικά και πολιτιστικά ζητήματα. Η σχετική αντίληψη και η γνώση των κατοίκων μπορεί να διαφέρει αισθητά και μάλιστα είναι αυτό που καθορίζει τις αποφάσεις τους σχετικά με την προσαρμογή των κοινωνιών στις συνθήκες πλημμυρικού κινδύνου ή απλά να την αγνόηση του.

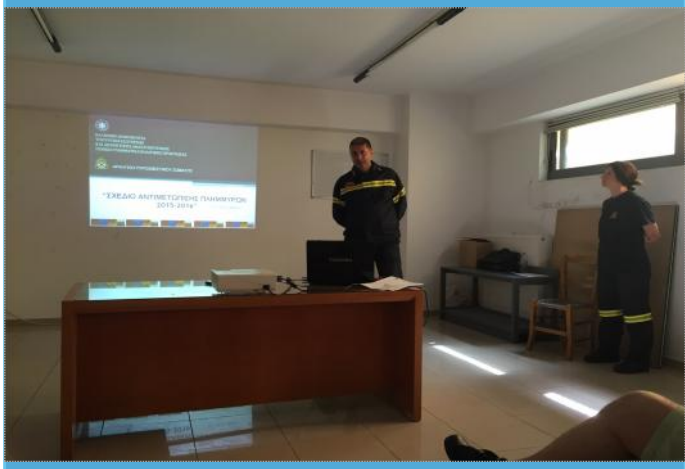
Το έργο PEARL επιδίωξε να καλύψει την έλλειψη αλληλεπίδρασης μεταξύ κοινωνικών πτυχών και τεχνικών αιτιών - που φαίνεται να αποτελεί σημαντικό εμπόδιο για την επίλυση μεγάλων προβλημάτων που συνδέονται με τις πλημμύρες και τις αντίστοιχες καταστροφές.

ΠΛΗΜΜΥΡΙΚΟΣ ΚΙΝΔΥΝΟΣ & ΔΙΑΧΕΙΡΙΣΗ



Flood Directive / Οδηγία 2007/60/EC

Implementation / Εφαρμογή



Management / Διαχείριση & Αντιμετώπιση

THE PEARL PROJECT: Methods & Tools

PEARL Project / Το έργο PEARL

Case Studies / Περιοχές μελέτης

Partners / Συμμετέχοντες Φορείς

The PEARL project, a collaborative research project with 4-year duration, worked towards the development of adaptive, socio-technical risk management measures and strategies for coastal communities against extreme hydro-meteorological events minimising social, economic and environmental impacts and increasing the resilience of Coastal Regions in Europe. PEARL received funding from the European Union's Seventh Framework Programme for Research, Technological Development and Demonstration (EU-FP7) under the theme "Coasts at threat in Europe: tsunamis and climate-related risks" (ENV.2013.6.4-3).

The PEARL consortium consisted of 24 partners from 13 countries from Europe and Asia, with significant experiences of severe flood risk in coastal regions and advanced flood early warning systems. Project's leader was the UNESCO-IHE.

The project examined 6 case studies from across Europe and 5 pilots from the Caribbean and Asia. Those were:

- Greve, Denmark
- Elbe Estuary, Germany
- Les Boucholeurs, France
- Genoa, Italy
- Marbella, Spain
- Rethymno, Crete, Greece
- St. Maarten
- St. Lucia
- Tohoku, Japan
- Taiwan
- Ayutthaya, Thailand

The research activities which were conducted within the project provided a plethora of products i.e. methodological frameworks, tools and applications, as well as policy briefs and publications. The most indicative ones were:

- Risk and Root Cause Assessment framework
- Vulnerability assessment framework
- Innovative hazard assessment and modelling concepts for individual or combined extreme events and several scales
- Frameworks for impact/damages (direct/indirect, tangible/intangible), economic and public health impact assessment due to multiple causes and scenarios
- Toolkit for holistic/multiple risk and impact/damage assessment at strategic and operational levels
- Operational Early Warning Systems and new methodologies for their effective dissemination
- Novel methodologies and concepts for achieving faster simulations and for uncertainty propagation analysis
- Frameworks for stakeholders' analysis and engagement i.e. the Learning and Action Alliances
- Frameworks and tools for flood resilience assessment of urban systems
- Intelligent knowledge base for resilience measures and strategies and tools/algorithms supporting their selection
- Interactive web-based learning and planning platform
- Risk Management Roadmaps specifically tailored to case study needs
- Information system infrastructure for data and meta data management

All outcomes/products and their integration formed the holistic approach and eventually the PEARL holistic framework enhancing prevention, mitigation and preparedness capabilities and building flood resilience of coastal urban systems.

ΤΟ ΕΡΓΟ PEARL

http://www.pearl-fp7.eu/

Το ερευνητικό έργο PEARL, ένα έργο συνεργασίας με 4ετή διάρκεια, επικεντρώθηκε στην ανάπτυξη μέτρων και στρατηγικών για τη διαχείριση του πλημμυρικού κινδύνου από ακραία υδρο-μετεωρολογικά φαινόμενα, λαμβάνοντας υπόψη και κοινωνικο-τεχνικούς παράγοντες, για τις παράκτιες περιοχές, ελαχιστοποιώντας παράλληλα την επίδραση στην κοινωνία, στην οικονομία και στο περιβάλλον και αυξάνοντας την ανθεκτικότητα έναντι των πλημμυρικών φαινομένων. Το έργο υλοποιήθηκε στα πλαίσια του 7ου Προγράμματος Πλαίσιο και χρηματοδοτήθηκε από την Γενική Διεύθυνση Έρευνας της Ευρωπαϊκής Επιτροπής.

Το έργο υλοποιήθηκε από σύμπραξη 24 φορέων από 13 χώρες της Ευρώπης και της Ασίας, με σημαντική εμπειρία στον κίνδυνο των πλημμυρών και τη διαχείρισή του, καθώς και στα προηγμένα συστήματα έγκαιρης προειδοποίησης πλημμυρών. Συντονιστής του προγράμματος ήταν ο φορέας UNESCO-IHE.

Στα πλαίσια του έργου εξετάστηκαν 6 πιλοτικές περιοχές της Ευρώπης και 5 της Καραϊβικής και της Ασίας. Αυτές ήταν:

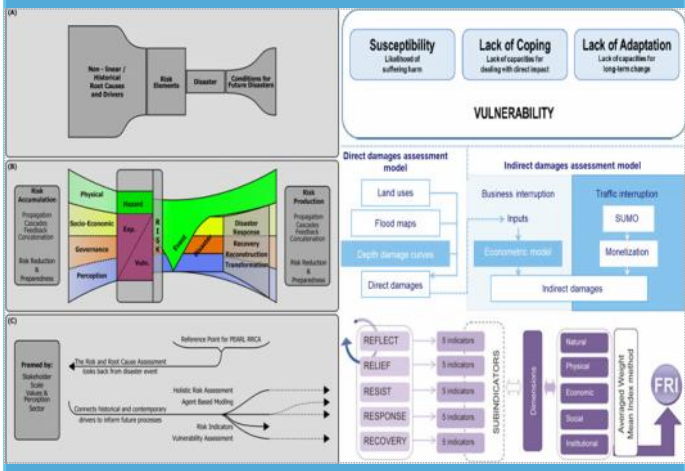
- Γκρέβε, Δανία
- Εκβολές Έλβα, Γερμανία
- Les Boucholeurs, Γαλλία
- Γένοβα, Ιταλία
- Μαρμπέγια , Ισπανία
- Ρέθυμνο, Κρήτη, Ελλάδα
- Άγιος Μαρτίνος
- Αγία Λουσία
- Tohoku, Ιαπωνία
- Ταϊβάν
- Ayutthaya, Ταϊλάνδη

Οι ερευνητικές εργασίες που εκπονήθηκαν παρήγαγαν πληθώρα προϊόντων όπως μεθοδολογικά πλαίσια, εργαλεία, εφαρμογές, ενημερωτικά δελτία και επιστημονικές δημοσιεύσεις. Τα πιο χαρακτηριστικά από αυτά είναι:

- Μεθοδολογικό πλαίσιο κατανόησης κινδύνων και αιτιών
- Μεθοδολογία αξιολόγησης της τρωτότητας
- Καινοτόμες λύσεις για την αξιολόγηση πλημμυρικών κινδύνων και μοντελοποίηση γεγονότων (μεμονωμένων ή συνδυαστικά) σε διάφορες κλίμακες
- Πλαίσια αξιολόγησης και εκτίμησης επιπτώσεων (άμεσες, έμμεσες, απτές και άυλες) στα αστικά συστήματα, στην οικονομία και την υγεία υπό διάφορα σενάρια
- Εργαλειοθήκη για την εφαρμογή ολιστικής προσέγγισης σε στρατηγικό και επιχειρησιακό επίπεδο
- Λειτουργικά Συστήματα Έγκαιρης Προειδοποίησης και μεθοδολογιών για την αποτελεσματική τους διάδοση
- Νέες μεθοδολογίες για την επίτευξη ταχύτερων προσομοιώσεων και για την ανάλυση διάδοσης αβεβαιότητας
- Μεθοδολογίες εμπλοκής και συμμετοχής φορέων
- Μεθοδολογίες και εργαλεία αξιολόγησης πλημμυρικής ανθεκτικότητας αστικών συστημάτων
- Έξυπνες γνωσιακές βάσεις μέτρων/στρατηγικών και αλγορίθμων για την επιλογή τους
- Δια δραστική πλατφόρμα εκμάθησης και σχεδιασμού
- Σχέδια Δράσης προσαρμοσμένα στις ανάγκες των περιοχών
- Συστήματα διαχείρισης και οργάνωσης δεδομένων και μεταδεδομένων

Όλα τα παραπάνω διαμόρφωσαν την ολιστική προσέγγιση του έργου PEARL για την ενίσχυση των δυνατοτήτων πρόληψης, μετριασμού και ετοιμότητας και την οικοδόμηση της αντοχής των παράκτιων αστικών συστημάτων έναντι των πλημμυρών.

ΤΟ ΕΡΕΥΝΗΤΙΚΟ ΕΡΓΟ PEARL: Μέθοδοι & Εργαλεία

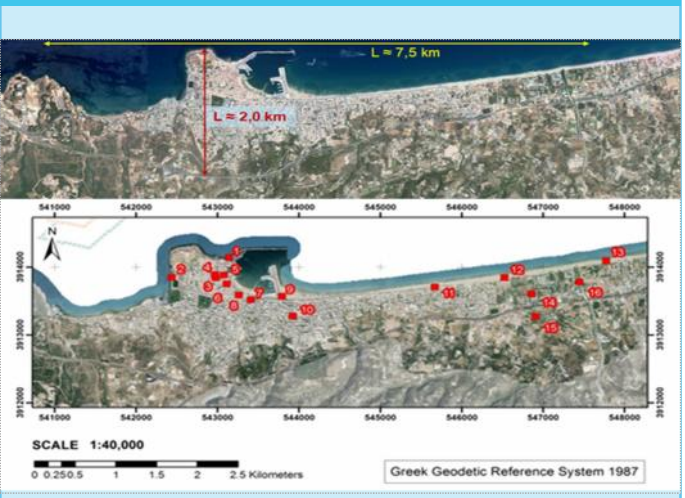


Methodologies / Μεθοδολογίες

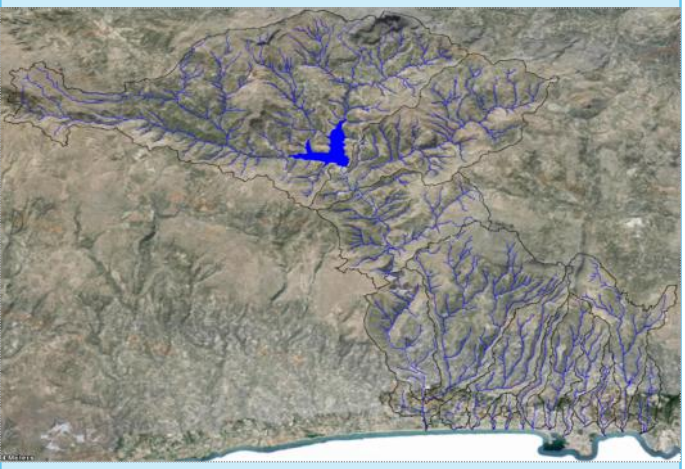
Tools & Application / Εργαλεία & Εφαρμογές

Publications & Policy Briefs / Δημοσιεύσεις

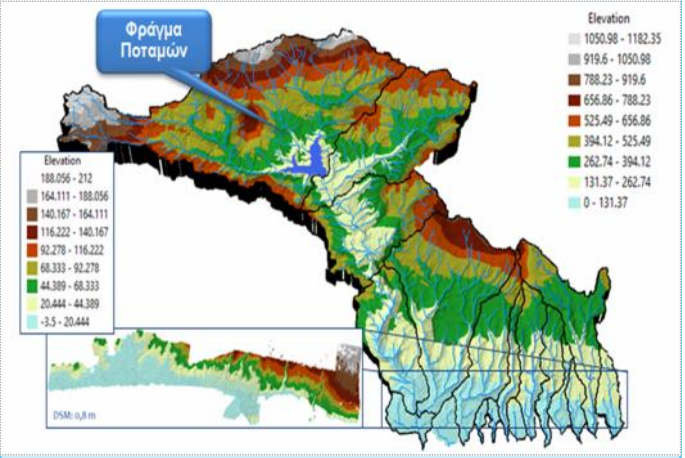
PROBLEM DESCRIPTION, ISSUES & CHALLENGES



Rethymno case study / Η περιοχή του Ρεθύμνου



River catchments / Υδρολογικές λεκάνες



Terrain & streams / Μορφολογία & ρέματα

Rethymno is situated at the Region of Crete in Greece and its population stands at 32,468 inhabitants according to Census 2011 with a density 140.12 population/km^2. As the 3rd most populous urban area of the island of Crete, commercial, administrative, cultural and tourist activities are being developed along the north coast where the city is located. The mean absolute altitude is 15 m and the length along the coastline of the area under study is 8 km.

For the city of Rethymno multiple stressors have always posed flood threats. The terrain and streams morphology convey volumes of storm water runoff from the upstream rural areas to the highly urbanised, flat downstream zones, pressurizing the drainage facilities and the flood defence infrastructures. The dominant strong northern and north-western winds highly affect the exposed coastal zone and result in the development of waves, which often overtop the harbour infrastructure and erode recreational beaches. Historic floods (1969–1999) led to adverse human, material, economic and environmental effects and eventually to the selection of prevention and mitigation measures, e.g. arrangement and diversion of streams and torrents, construction of circular storm water drainage collectors, internal-primary drainage network and flood control dams. Nevertheless, both the urban and coastal areas are still subjected to flood problems, e.g. extensive damages to windward breakwaters of the harbour and backwater effects at drainage network outfalls as experienced during recent flood events (2010–2015). As such, the need to manage flood risk through a more integrated approach which would also be coupled with stakeholder involvement was initially identified and eventually formed the primary goals for the specific case study.

The challenges encountered in the beginning of PEARL project where related to hazard i.e. the simulation of multiple hazards and types of flood which required coupling of multiple models in different spatial and temporal scales. The missing data was one more difficulty faced. Such data were discharge measurements necessary for models' calibration, the absence of the sewerage and stormwater network in digital format in order to be included within the setup of hydraulic models and finally the plans of infrastructures (closed conduits) crossing the urban area and leading stormwater from river beds to the sea. The latter was handled by designing the route of closed parts of river beds based on the road network (studied from the high resolution ortho-photographs available in the case study), logical assumptions related to slopes and elevations of closed part of the network and available textual information in case study reports. One more challenge was the long computational time of simulations while utilising data of high resolution (e.g. Digital Surface Model of 0.8 m).

The absence of a responsible authority and flood management plans, unclear jurisdictions among existing authorities, low preparedness and flood risk awareness of citizens, civil engineers, authorities, etc. where challenges faced within stakeholder engagement activities, as well as the comprehension of roots and causes of severe past flood events, specifically in terms of social aspects. All the above challenges were handled within PEARL and it became clear that providing tangible results and tools to the city of Rethymno was of primary importance.

Η ΠΕΡΙΟΧΗ ΜΕΛΕΤΗΣ

Η περιοχή μελέτης του Ρεθύμνου βρίσκεται στην Περιφέρεια Κρήτης και ο πληθυσμός της, σύμφωνα με τα στοιχεία της απογραφής του 2011, ανέρχεται σε 32,468 κατοίκους με πυκνότητα πληθυσμού ίση με 140.12 κατ./km^2. Ως το 3^o πολυπληθέστερο αστικό κέντρο της Κρήτης, στην πόλη και συγκεκριμένα στη βόρεια πλευρά του νησιού έχει αναπτυχθεί έντονη εμπορική, διοικητική, πολιτιστική και τουριστική δραστηριότητα. Το μέσο υψόμετρο της περιοχής είναι περίπου στο +15 και η απόσταση κατά μήκος της ακτογραμμής ανέρχεται στα 8 km.

Πολλαπλοί παράγοντες ανέκαθεν έθεταν την πόλη του Ρεθύμνου υπό τον πλημμυρικό κίνδυνο. Η μορφολογία της περιοχής και τα υπάρχοντα ρέματα που διοδεύουν σημαντικές ποσότητες όμβριων υδάτων από τις ανάντη περιοχές στις κατάντη έντονα αστικοποιημένες ζώνες, καθώς και οι ήπιες κλίσεις κοντά στην ακτογραμμή διαμόρφωναν σημαντικές πιέσεις στις αντιπλημμυρικές υποδομές και τα δίκτυα. Οι επικρατούντες Β και ΒΔ άνεμοι επιδρούν σημαντικά στο εκτεθειμένο αμμώδες παραλιακό μέτωπο και συχνά διαμορφώνουν υψηλά κύματα που καταλήγουν στη έντονη και βίαιη κυματική υπερπήδηση των λιμενικών εγκαταστάσεων και στη διάβρωση των ακτών.

Ιστορικές πλημμύρες (1969 – 1999) είχαν δυσμενείς επιπτώσεις στις ζωές την κατοίκων, στα υλικά αγαθά, την οικονομική δραστηριότητα και στο περιβάλλον και δημιούργησαν τα κίνητρα για την κατασκευή αρκετών αντιπλημμυρικών έργων και συγκεκριμένα κατασκευαστικών, όπως διευθετήσεις χειμάρρων, κατασκευή έργων αποστράγγισης και κύριων συλλεκτήρων, εκτροπές απορροών και φράγματα ανάσχεσης πλημμυρικών αιχμών. Παρ' όλα αυτά, η αστική και παράκτια πλημμύρα αποτελούν υπαρκτούς κινδύνους για την πόλη και τις υποδομές της π.χ. πρόκληση εκτενών ζημιών στον προσήνεμο κυματοθραύστη των λιμενικών εγκαταστάσεων, αντιστροφή ροής στις εξόδους του δικτύου ομβρίων όπως συνέβη κατά τα πιο πρόσφατα γεγονότα πλημμύρας (2010-2015). Κατά συνέπεια, η ανάγκη διαχείρισης του κινδύνου των πλημμυρών μέσω μιας ολοκληρωμένης προσέγγισης που θα λαμβάνει υπόψη και θα επιτρέπει την εμπλοκή των ενδιαφερομένων μερών/φορέων αποτελέσαν έναν από τους βασικότερους στόχους του έργου.

Οι προκλήσεις που αντιμετωπίστηκαν στα πλαίσια του έργου σχετίζονταν με την προσομοίωση πολλαπλών τύπων πλημμύρας που απαιτούσε συνδυασμένη χρήση λογισμικών σε διάφορες χωρικές και χρονικές κλίμακες. Η απουσία δεδομένων ήταν ακόμα μία πρόκληση π.χ. καταγεγραμμένων παροχών, η ψηφιακή μορφή αρχείων υφιστάμενων υποδομών και κλειστών τμημάτων ρεμάτων εντός αστικού ιστού. Μέρος των άνω δυσκολιών διευθετήθηκαν με χρήση δεδομένων ορθοφωτοχαρτών, υιοθέτηση εύλογων παραδοχών και περιγραφές διαθέσιμων αναφορών/μελετών. Οι μεγάλοι υπολογιστικοί χρόνοι ήταν μία πρόσθετη δυσκολία λόγω της αξιοποίησης υψηλής ανάλυσης δεδομένων. Η απουσία μίας δομής υπεύθυνης για την αντιπλημμυρική προστασία την πόλης, τα ασαφή όρια δικαιοδοσίας μεταξύ φορέων, η χαμηλή σχετικά ετοιμότητα και η άγνοια των κατοίκων και της κοινωνίας για τον κίνδυνο των πλημμυρών αποτέλεσαν σημεία εστίασης καθώς και τα βαθύτερα αίτια των σημαντικότερων πλημμυρικών γεγονότων (λαμβάνοντας υπόψη και τις κοινωνικές πτυχές του φαινομένου). Όλες οι παραπάνω προκλήσεις αντιμετωπίστηκαν μέσα στο PEARL και κατέστη σαφές ότι η παροχή απτών αποτελεσμάτων και εργαλείων για την πόλη ήταν πρωταρχικής σημασίας.

ΠΕΡΙΓΡΑΦΗ ΠΡΟΒΛΗΜΑΤΟΣ & ΠΡΟΚΛΗΣΕΙΣ

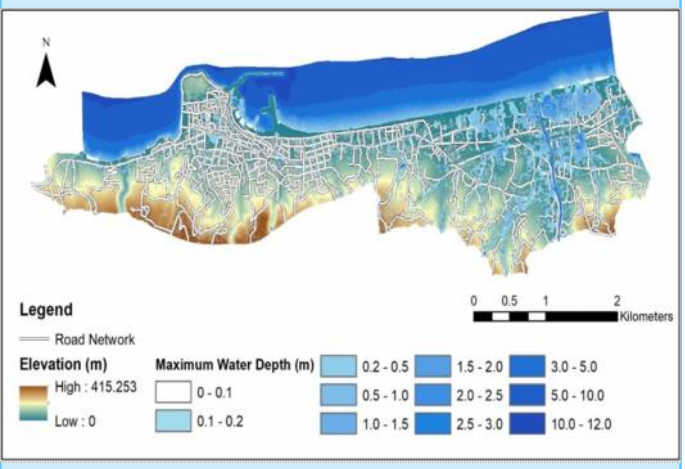
Wave overtopping / Κυματική υπερπήδηση

1999 floods event / Πλημμύρα 1999

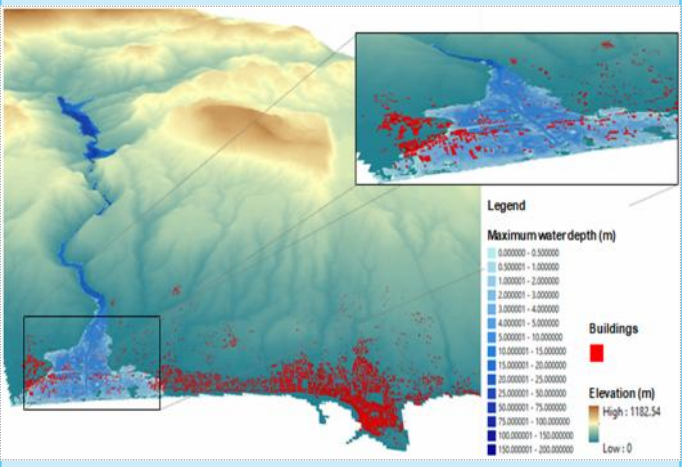
Flood impact / Επιπτώσεις πλημμυρών

PEARL OUTCOMES

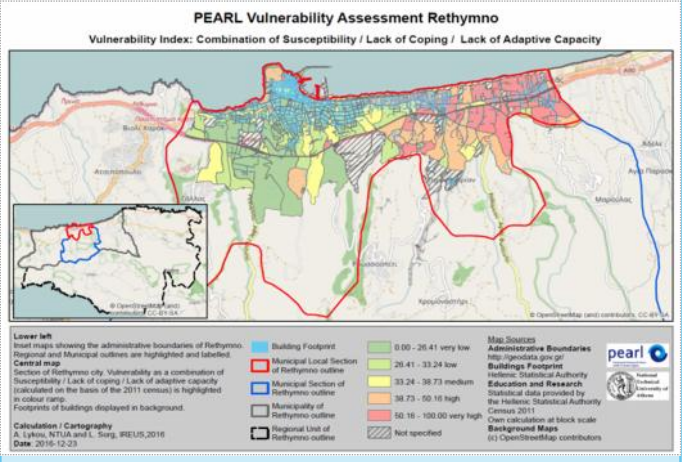
highlighting what needs to be done towards a more flood resilient city



Flood map / Πλημμυρικός χάρτης



Dam break / Θραύση φράγματος



Vulnerability map / Χάρτης τρωτότητας

Due to the integrated and holistic approach of the project, research activities focused, not only at the natural root and causes of flood phenomena i.e. the coastal and/or urban floods, the extreme hydro-meteorological events, etc., but also at social (e.g. governance, institutional arrangements, planning, policies and norms, cultural issues, etc.) and technical aspects (existing flood defence infrastructures, etc.). The Risk and Root Cause Assessment framework revealed weaknesses which are related to the decision-making processes. For the exploration of different perceptions and risks of citizens, a household survey was conducted, the results of which contributed in the estimation of city's social vulnerability. The analysis of census data (year 2011) enabled the vulnerability assessment and the configuration of different zones based on its values.

While trying to understand formation of hazards under extreme events, different software packages and modelling frameworks were developed/applied in different spatial and time scales, for the simulation of hydrological and hydrodynamic processes from the origin of the river basins until the sea. Different scenarios where examined though the modelling work, mostly hydro-meteorological, but also failure of infrastructure. Moreover, due to the long computational time, different techniques achieving faster simulation were tested.

After the conduction of simulations, the extraction of multiple hydrodynamic parameters/results and the development of flood maps, which were combined with the already available vulnerability values, estimation of flood risk and its zoning was achieved. Maximum water depth and velocities values were considered more crucial within hazard assessment.

Research activities were concentrated in the development and provision of tools for Rethymno's authorities, tools aiming to enhance decision making processes towards the increase of city's flood resilience. Tools and application which were developed and/or applied in Rethymno were:

- The PearlDetective
  - õ The PEARL Knowledge Base
  - õ The PEARL Online Flood Resilience Index Tool
  - õ The PEARL Toolbox
  - õ The PEARL ABM SAS
  - õ The PEARL Web Learning and Planning Platform

Stakeholders' engagement in all stages of research activities was sought from the very first day of the project through the organisation of multiple activities, discussions and questionnaires structured while following the LAA framework. Towards that purpose, several technical meetings were scheduled with the authorities, as well as three LAA workshops (1-2/10/2015, 7-8/06/2016, 29/9/2017).

The PEARL approach which was applied with the scope of improving flood risk management developed and provided a plethora of methodological frameworks and tools covering several aspects and study stages of flood phenomena, while at the same time highlighted major flood problems of the area under study and provided valuable suggestions to improve or even resolve them.

Εξαιτίας της ολοκληρωμένης προσέγγισης του έργου, οι εργασίες κατανόησης του κινδύνου των πλημμυρών, δεν εστίασαν μόνο στις φυσικές διεργασίες του φαινομένου (π.χ. παράκτια ή/και αστική πλημμύρα, έντονα υδρο-μετεωρολογικά φαινόμενα, κ.λπ.), αλλά και στα βαθύτερα κοινωνικά (π.χ. διακυβέρνηση, θεσμικές ρυθμίσεις, πολιτικές, σχεδιασμός τοπικών φορέων, πεποιθήσεις και ευαισθητοποίηση κατοίκων, κ.λπ.) και τεχνικά αίτια (υφιστάμενα έργα αντιπλημμυρικής προστασίας, κ.λπ.). Η μεθοδολογία Risk and Root Cause Assessment ανέδειξε αδυναμίες που σχετίζονται με την διακυβέρνηση. Για τη διερεύνηση των αντίληψης και γνώσης των κατοίκων έναντι των πλημμυρών διενεργήθηκε κατ' οίκων έρευνα με ερωτηματολόγια τα αποτελέσματα της οποίας συνεισέφεραν στη διαμόρφωση της κοινωνικής τρωτότητας της περιοχής. Η επεξεργασία και η ανάλυση των στοιχείων απογραφής της ΕΛΣΤΑΤ (έτος 2011) έκανε εφικτή την εκτίμηση της τρωτότητας σε ζώνες.

Για την κατανόηση των μηχανισμών πλημμυρικού κινδύνου συνδυάστηκαν και εφαρμόστηκαν πολλά λογισμικά και μέθοδοι, σε διάφορες χωρικές και χρονικές κλίμακες, με στόχο την προσομοίωση των φυσικών μηχανισμών από τα όρια των υδρολογικών λεκανών ως τη θάλασσα. Σενάρια που εξετάστηκαν ήταν κυρίως υδρο-μετεωρολογικά αλλά και σενάρια αστοχίας υποδομών. Πρόσθετα διερευνήθηκαν τεχνικές μείωσης του υπολογιστικού φόρτου ή/και αύξησης των ταχυτήτων προσομοίωσης.

Έπειτα τη διενέργεια προσομοιώσεων και την παραγωγή χαρτών υδροδυναμικών μεγεθών αλλά και της τρωτότητας, έγινε εφικτή η κατηγοριοποίηση ζωνών διαφορετικού κινδύνου και τελικά ζωνών διακινδύνευσης με κρισιμότερες τις παραμέτρους του μέγιστου βάθους ροής και των ταχυτήτων.

Οι ερευνητικές προσπάθειες επικεντρώθηκαν και στην ανάπτυξη και τελικά την παροχή εργαλείων στους Φορείς για την ενίσχυση των διαδικασιών λήψης απόφασης προς την κατεύθυνση της ενίσχυσης της πλημμυρικής ανθεκτικότητας. Εργαλεία που αναπτύχθηκαν ή/και εφαρμόστηκαν στο Ρέθυμνο ήταν:

- The PearlDetective
- The PEARL Knowledge Base
- The PEARL Online Flood Resilience Index Tool
- The PEARL Toolbox
- The PEARL ABM SAS
- The PEARL Web Learning and Planning Platform

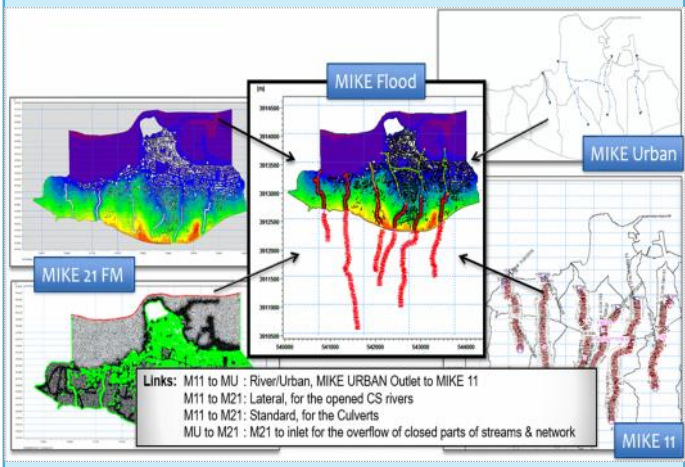
Η εμπλοκή των Φορέων και Ενδιαφερομένων σε όλα τα στάδια των ερευνητικών εργασιών επιδιώχθηκε από την πρώτη μέρα του έργου μέσα από τη διοργάνωση δράσεων, συζητήσεων και ερωτηματολογίων δομημένων μέσα από τη μεθοδολογία LAA. Για το σκοπό αυτό διοργανώθηκε πληθώρα τεχνικών συναντήσεων με τους φορείς και τρία συμμετοχικά εργαστήρια (1-2/10/2015, 7-8/06/2016, 29/9/2017).

Η ολοκληρωμένη προσέγγιση του έργου που εφαρμόστηκε με στόχο τη διαχείριση του κινδύνου των πλημμυρών παρείχε αρκετά μεθοδολογικά πλαίσια και εργαλεία καλύπτοντας πολλές πτυχές και στάδια μελέτης των πλημμυρικών φαινομένων, ενώ παράλληλα ανέδειξε τα σημαντικότερα προβλήματα της πόλης, καθώς και συγκεκριμένες προτάσεις για την βελτίωση ή ακόμα και επίλυσή τους.

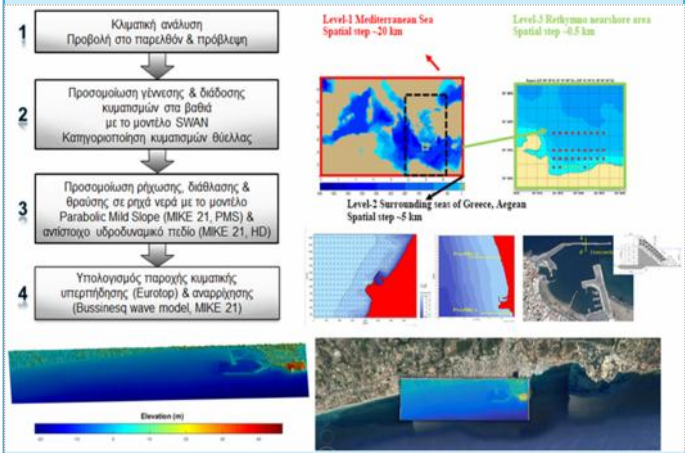
PEARL ΑΠΟΤΕΛΕΣΜΑΤΑ

αναδεικνύοντας τι πρέπει να γίνει για μια πιο ανθεκτική στην πλημμύρα πόλη

PEARL approach / Προσέγγιση PEARL



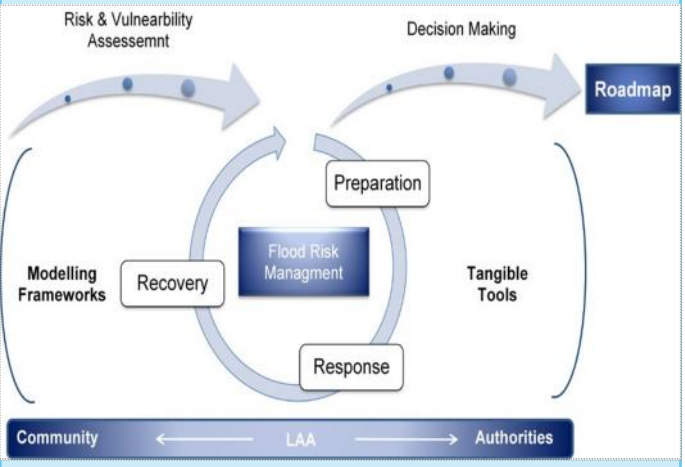
Flood simulation / Προσομοίωση πλημμύρας



Coastal simulations / Παράκτιες προσομοιώσεις

THE ROLE OF LAAs, STAKEHOLDERS' & CITIZENS' PARTICIPATION

LAA workshop / Συμμετοχικό εργαστήριο



Roadmap approach / Προσέγγιση σχεδίου δράσης

Forming the LAA / Διαμορφώνοντας το LAA

Societies are challenged to reform/adapt flood management systems to cope with altered threats by implementing more efficient decision-making procedures and preventive solutions. Increased stakeholder involvement is required in order to achieve effective risk governance and preparedness of local societies to manage extreme events. A primary objective of PEARL, apart from the development of a holistic risk reduction framework, was the development of tools that would strengthen risk governance by actively involving local actors.

It is identified that flood management needs a change from the current technocratic approach to a more socio-central one. To this aim there is a need for breaking the traditional approach of engineers and decision makers and include them in an interactive social learning procedure. To achieve active learning and multi stakeholder approach the methodology of Learning and Action Alliances (LAAs) was applied in Rethymno.

"A Learning and Action Alliance is a convention of individuals and/or organisations who are involved in or affected by decision making processes and their outcome in the context of risk and/or disaster management, or any other political and economic decision that could alter the group members' situation or capacities before, during or after an extreme event."

The alliance worked as a bridge among science, government and society, while its' ultimate goal was the production of an actionable Roadmap with the community's consensus, a strategic risk management plan for the city's flood resilience increase.

PEARL researchers proceeded to a stakeholders' analysis, various technical meetings with key authorities, and the implementation of three participatory workshops where all local actors were represented. Aims of the workshops were the LAA establishment and the gaining of knowledge regarding area's specific particularities. Moreover, PEARL's tools were demonstrated and lively tested by stakeholders. In this way the applicability and utility of those tools were evaluated directly by the potential end users. Through the active learning process locals in Rethymno managed: to identify the city's level of vulnerability to extreme events; to exchange knowledge on existing flood problems and infrastructures; to explore different flood risk perceptions; to identify gaps in decision making procedure or overlapping of responsibilities in the several levels of hierarchy; to examine and select the most suitable measures for their city. LAA aimed and resulted to a high involvement of local society, which produced a bidirectional exchange of knowledge and a bottom up approach of a Roadmap design for Rethymno city.

The most important achievement is that sufficient justification was provided on why Rethymno should be considered as a potential significant high-risk area within the EU Flood Directive work. Consequently, PEARL supported the authorities' future actions on funds' claiming, which will enable the implementation of new flood resilience measures in the city.

Finally, all stakeholders agreed on the continuation of the LAA through the group's official establishment under the Consultation Committee of Rethymno's Municipality.

Οι κοινωνίες καλούνται να αναθεωρήσουν τον υπάρχον τρόπο διαχείρισης πλημμύρων ώστε να αντιμετωπίσουν συνεχώς μεταβαλλόμενους κινδύνους, υλοποιώντας πιο αποτελεσματικές διαδικασίες λήψης αποφάσεων και προωθώντας δράσεις πρόληψης. Η ενεργή συμμετοχή πολλαπλών φορέων είναι προϋπόθεση για την επίτευξη αποτελεσματικής διακυβέρνησης και την προετοιμασία των τοπικών κοινωνιών έναντι ακραίων φαινομένων. Βασικός στόχος του PEARL πέραν της ανάπτυξης ενός ολιστικού πλαισίου μείωσης του πλημμυρικού κινδύνου ήταν και η δημιουργία εργαλείων ενίσχυσης της διακυβέρνησης με την ενεργή συμμετοχή των τοπικών κοινοτήτων. Διαπιστώνεται η ανάγκη για μία στροφή στη διαχείριση των ακραίων φαινομένων, από την επικρατούσα τεχνο-κρατική προσέγγιση σε μία πιο κοινωνιο-κεντρική. Χρειάζεται να επέλθει μία αλλαγή στην παραδοσιακή νοοτροπία τόσο των ειδικών, μηχανικών όσο και των κέντρων λήψης απόφασης ώστε να συμμετέχουν από κοινού σε μία διαδικασία κοινωνικής μάθησης και συμμετοχής στη διαχείριση πλημμύρων. Για την επίτευξη αυτού εφαρμόστηκε στο Ρέθυμνο η μεθοδολογία της Συμμαχίας Μάθησης και Δράσης (LAA).

«Μία Συμμαχία Μάθησης και Δράσης είναι μία σύμπραξη ατόμων ή/και φορέων που εμπλέκονται ή/και επηρεάζονται στη διαδικασία λήψης αποφάσεων και στις σχετικές πολιτικές-οικονομικές αποφάσεις, σε ότι αφορά τη διαχείριση κινδύνων από πλημμύρες, και των οποίων η δράση δύναται να επηρεάσει τις συνθήκες πριν, μετά και κατά τη διάρκεια ενός ακραίου φαινομένου».

Η LAA στο Ρέθυμνο αποτέλεσε μία γέφυρα επικοινωνίας μεταξύ της επιστημονικής κοινότητας, της τοπικής αυτοδιοίκησης και της κοινωνίας. Βασικός στόχος της υπήρξε ο σχεδιασμός ενός βιώσιμου Στρατηγικού σχεδίου δράσης για το Ρέθυμνο, με τη συναίνεση της τοπικής κοινωνίας, για την ενίσχυση της ανθεκτικότητας της πόλης έναντι πλημμυρικών κινδύνων.

Οι ερευνητές έπειτα από ανάλυση του θεσμικού πλαισίου, προχώρησαν σε τεχνικές συναντήσεις με φορείς στο Ρέθυμνο, καθώς και στην υλοποίηση τριών διαδραστικών συμμετοχικών εργαστηρίων. Στόχοι των δράσεων αυτών υπήρξαν αφενός η δημιουργία της LAA και η ανταλλαγή εμπειρίας και τεχνογνωσίας για την κατανόηση της ιδιαιτερότητας της πόλης, και αφετέρου η επίδειξη των τεχνολογικών εργαλείων που αναπτύχθηκαν από το PEARL και οι δυνατότητες αξιοποίησης τους από την τοπική αυτοδιοίκηση. Μέσω της συμμετοχικής διαδικασίας οι τοπικοί φορείς κατάφεραν να: αναγνωρίσουν το επίπεδο της τρωτότητας της πόλης τους σε πλημμύρες, ανταλλάξουν γνώση για τα προβλήματα και τις υπάρχουσες υποδομές, εξερευνήσουν τις διαφορετικές αντιλήψεις γύρω από τον πλημμυρικό κίνδυνο, εντοπίσουν τις ελλείψεις στη διακυβέρνηση ή την αλληλεπικάλυψη αρμοδιοτήτων, εξετάσουν και επιλέξουν τα πιο κατάλληλα μέτρα αντιπλημμυρικής προστασίας για την πόλη. Η διαδικασία πέτυχε έναν υψηλό βαθμό συμμετοχής των φορέων με αποτέλεσμα τη δημιουργία ενός Σχεδίου δράσης *«από τα κάτω προς τα πάνω»*. Το πιο σημαντικό όμως επίτευγμα υπήρξε το ότι παράχθηκε αρκετή αιτιολόγηση για την προσθήκη του Ρεθύμνου στις περιοχές πιθανού υψηλού ρίσκου στο πλαίσιο της Οδηγίας για τις Πλημμύρες (2007/60/ΕΚ), ενώ οι εταίροι συμφώνησαν στη συνέχεια της LAA μέσω της ενσωμάτωσης της στην Επιτροπή Συμβούλων του Δήμου.

Ο ΡΟΛΟΣ ΤΗΣ ΣΥΜΜΑΧΙΑΣ ΜΑΘΗΣΗΣ & ΔΡΑΣΗΣ , ΤΩΝ ΦΟΡΕΩΝ & ΤΩΝ ΚΑΤΟΙΚΩΝ

Collaboration / Συνεργασία

Alliance / Συμμαχία

Knowledge exchange / Ανταλλαγή γνώσης

PARTIES INVOLVED

Engaging stakeholders / Εμπλέκοντας φορείς

Engaging stakeholders / Εμπλέκοντας φορείς

Engaging stakeholders / Εμπλέκοντας φορείς

Primary objective of the Rethymno LAA was the development of the **Risk Management Roadmap** which will serve as a strategic plan with phased interventions aiming at increasing city's flood risk resilience. The Roadmap was produced with the consensus of all key local actors who are involved in decision making procedure regarding flood risk management.

Through the research work and consultation process during the project, the identified authorities/services and/or groups that were represented and actually formed the Rethymno's LAA were:

- Municipality of Rethymno: Civil Protection Service, Technical Department, Planning-Development and Innovation Department
- Regional Unit of Rethymno: Civil Protection Service, Technical Department, Planning-Development and Innovation Department
- Decentralized Administration of Crete: Water Resources Directorate
- Municipal Port Authority of Rethymno
- Municipal Water Supply and Sewerage Company
- Fire Service of Rethymno: Direction of Operations
- Institute of Geology and Mineral Exploration (Crete Department)
- Development Organisation of Crete: Direction of Transportation and Hydraulic works
- 2 Local NGOs: Civil Protection Volunteers Team and SINPOLIS (Group of active citizens)
- Civil Society /Citizens: Former Mayor, Former Deputy Mayor

The above local community's representatives participated in all technical meetings and workshops and they were exposed to PEARL's outcomes and research results (planning tools and modelling /simulation results).

Through their interaction and commitment to the LAA's aims it was achieved to get a comprehensive view of Rethymno's flood problems. Their collaboration with the research team provided valuable knowledge for: the current city's flood defence, their future goals and ambitions, the interdependencies among the different authorities, the flow of information and the hierarchy in flood related issues, their risk perceptions and the knowledge of how flood events affect the city's daily life.

As a result of the active learning procedure the involved parties managed to commonly design a tailored Roadmap viable and applicable in Rethymno. The Rethymno strategic plan includes measures and activities whose implementation is possible within the near future. These actions were classified under three axes:

- Actions aiming to enhance decision making processes and flood risk governance
- Actions strengthening information and raising flood risk awareness
- Actions assisting in city's flood preparation and protection

Each axis contains a set of measures and activities both structural and operational, while each involved party serves a different role and bares a different level of responsibility for the actual implementation of them.

Πρωταρχικός σκοπός της LAA στο Ρέθυμνο υπήρξε η δημιουργία ενός Στρατηγικού Σχεδίου δράσης διαχείρισης πλημμυρικού κινδύνου συμπεριλαμβανομένων σταδίων υλοποίησης που στοχεύει στην αύξηση της ανθεκτικότητας της πόλης έναντι πλημμυρικών φαινομένων. Το Σχέδιο δράσης παράχθηκε με τη συμμετοχή και συναίνεση όλων των τοπικών φορέων που εμπλέκονται στις σχετικές διαδικασίες λήψης απόφασης. Μέσω της ερευνητικής διαδικασίας και της διαβούλευσης στο πλαίσιο του PEARL οι φορείς/υπηρεσίες που αναγνωρίστηκαν ως κρίσιμοι και τελικά συμμετείχαν στην Συμμαχία του Ρεθύμνου είναι :

- Δήμος Ρεθύμνου: Υπηρεσία Πολιτικής Προστασίας, Τεχνική Υπηρεσία, Τμήμα Σχεδιασμού, Έρευνας και Ανάπτυξης
- Περιφερειακή Ενότητα Ρεθύμνου: Υπηρεσία Πολιτικής Προστασίας, Τεχνική Υπηρεσία, Τμήμα Σχεδιασμού, Έρευνας και Ανάπτυξης
- Αποκεντρωμένη Διοίκηση Κρήτης: Διεύθυνση Υδάτων
- Λιμενικό Ταμείο Ρεθύμνου
- Δημοτική Επιχείρηση Ύδρευσης και Αποχέτευσης Ρεθύμνου
- Πυροσβεστική Υπηρεσία Ρεθύμνου: Διεύθυνση Επιχειρήσεων
- Ινστιτούτο Γεωλογικών και Μεταλλευτικών Ερευνών (Παράρτημα Κρήτης)
- Οργανισμός Ανάπτυξης Κρήτης: Διεύθυνση Μεταφορών και Υδραυλικών έργων
- Τοπικές ΜΚΟ: Εθελοντική Ομάδα Πολ. Προστασίας και SINPOLIS (ομάδες ενεργών πολιτών)
- Πολίτες: Πρώην Δήμαρχος, Πρώην Αντιδήμαρχος

Οι παραπάνω εκπρόσωποι της τοπικής κοινωνίας συμμετείχαν σε όλες τις τεχνικές συναντήσεις και τα συμμετοχικά εργαστήρια και κατά αυτόν εκτέθηκαν στην ερευνητική διαδικασία και στα αποτελέσματα του PEARL (εργαλεία, αποτελέσματα προσομοιώσεων κα μοντελοποίησης). Μέσω της διάδρασης μεταξύ τους αλλά και με την ερευνητική ομάδα καθώς και μέσω της δέσμευσης τους στους στόχους της LAA επιτεύχθηκε η διαμόρφωση μίας πλήρους εικόνας για τα πλημμυρικά προβλήματα στο Ρέθυμνο. Η συνεργασία τους με τους ερευνητές παρήγαγε σημαντική γνώση για: τις υπάρχουσες υποδομές και αντιπλημμυρική προστασία της πόλης, τους μελλοντικούς στόχους και επιδιώξεις, τις αλληλεξαρτήσεις και τα κανάλια επικοινωνίας μεταξύ των διαφορετικών αρχών, τις αντιλήψεις για τον πλημμυρικό κίνδυνο και τη γνώση για το πως επηρεάζουν οι πλημμύρες την καθημερινή ζωή της πόλης.

Ως αποτέλεσμα αυτής της διαδικασίας ενεργής μάθησης ήταν η από κοινού δημιουργία ενός εφαρμόσιμου σχεδίου δράσης επεξεργασμένου ακριβώς με βάση τις ιδιαίτερες ανάγκες του Ρεθύμνου. Το σχέδιο δράσης περιλαμβάνει μέτρα των οποίων η υλοποίηση είναι εφικτή στο κοντινό μέλλον ενώ οι προτεινόμενες δράσεις ταξινομούνται σε τρείς διακριτούς άξονες:

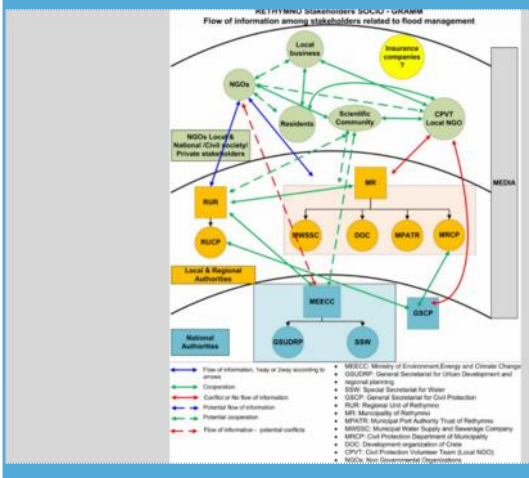
- Ενίσχυση της διαδικασίας λήψης αποφάσεων & διακυβέρνησης
- Ενδυνάμωση της πληροφόρησης & ευαισθητοποίησης
- Υποστήριξη της αντιπλημμυρικής προετοιμασίας & προστασίας

Ο κάθε άξονας περιλαμβάνει τόσο διαρθρωτικά, κατασκευαστικά όσο και επιχειρησιακά μέτρα ενώ ο κάθε φορέας φέρει διαφορετικό ρόλο και βαθμό ευθύνης για την υλοποίηση τους.

ΕΝΔΙΑΦΕΡΟΜΕΝΟΙ ΦΟΡΕΙΣ

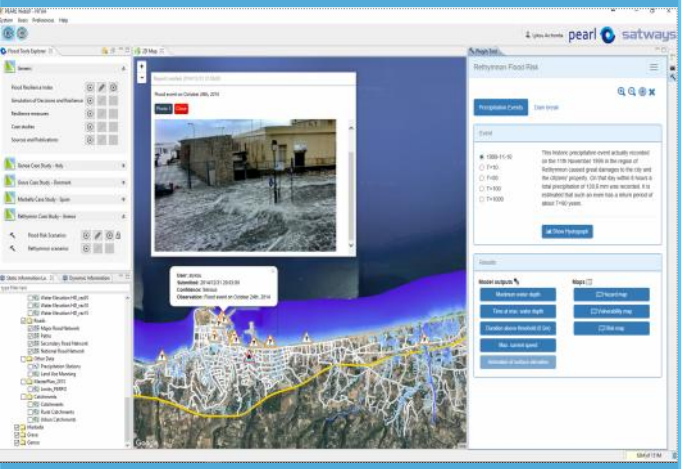
Engaged parties / Εμπλεκόμενοι φορείς

Engaged parties / Εμπλεκόμενοι φορείς

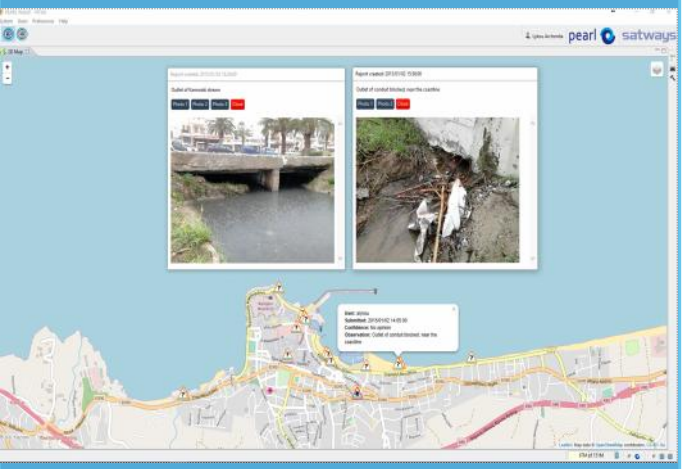


Sociogram / Οργανόγραμμα φορέων

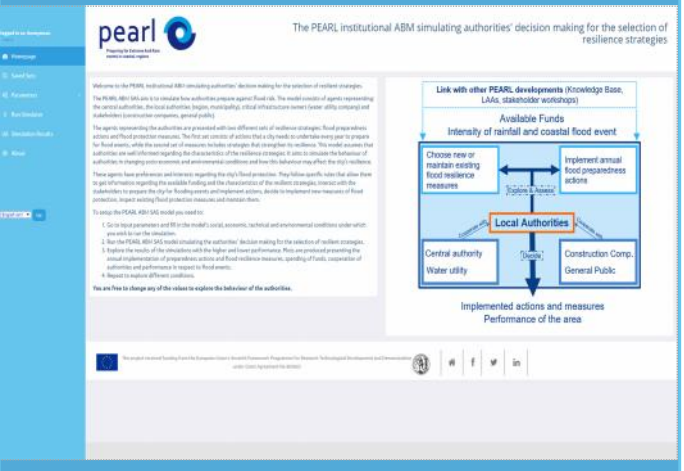
GROUP OF ACTIVITIES 1: Enhancing decision making processes & governance



PEARL Web Learning and Planning Platform



PEARL Detective application



PEARL ABM SAS

PEARL activities revealed key aspects of the decision-making processes and the governance such as the leading role of the Fire Service when flood event occurs and the exclusion of Rethymno case from the areas which are considered of potential high flood risk as per the EU Flood Directive and the preliminary assessment results. Moreover, insufficient cooperation and coordination among authorities and absence of clear jurisdiction & difficulties in allocation of roles was occasionally highlighted.

To tackle the abovementioned difficulties, a group of activities was commonly suggested. Those were:

- Action 1: Collection of **flood reports from the field** by the technical department of authorities by using the PEARL detective
- Action 2: **Continuation of the LAA and its official establishment** under an existing authority serving as an interface between authorities and society
- Action 3: **Development of flood protection plans** by using the WebLP, the uploaded scenarios & results
- Action 4: **Official use (by each authority) and strengthening of multi-agency collaboration & coordination** by using the WebLP
- Action 5: **Revision of urban planning** by taking into consideration flood zones by using the WebLP and the simulated scenarios
- Action 6: **Drafting of new proposal requesting funding** by using the PEARL KB e.g. in the framework of Regional Operational Programs for finding flood control measures combined with other actions aiming at aesthetically upgrading areas, lessening of noise level, etc.
- Action 7: **Annual meeting of authorities** for knowledge exchange & update related to the flood preparation and protection of the city while utilising the online FRI tool, the KB and the ABM SAS

The possible future implementation of each activity raised concerns and motivated a fruitful discussion. Specifically, for the continuation of the LAA, it was commonly agreed that it should be established under an existing and already functioning authority i.e. the Consultation Committee of Rethymno's Municipality. On the contrary, the establishment of a completely new structure was deemed ineffective since it would eventually be converted into an inactive one without any added value for the city. The development of flood protections plans was suggested to be led by the Civil Protection Authority, as well as the initiative of organising the annually meetings related to the flood preparation and protection of the city. Regarding the multi-agency collaboration and knowledge exchange, information related to existing arrangements of streams (already available under the Government Gazette) and the revision of the latest urban planning by incorporating flood inundation zones were suggested to be uploaded onto the PEARL WebLP, as a starting point. The Operational Program for the Environment and Sustainable Development and the Regional Operational Program are primary funding frameworks for the city for which the PEARL tools might be used during proposal drafting. Future strategies assessment by authorities under different socio-economic conditions and flood scenarios by using the PEARL ABM SAS was one more suggested activity, but it was considered difficult for implementation. Nevertheless, it received great interest from the engaged parties.

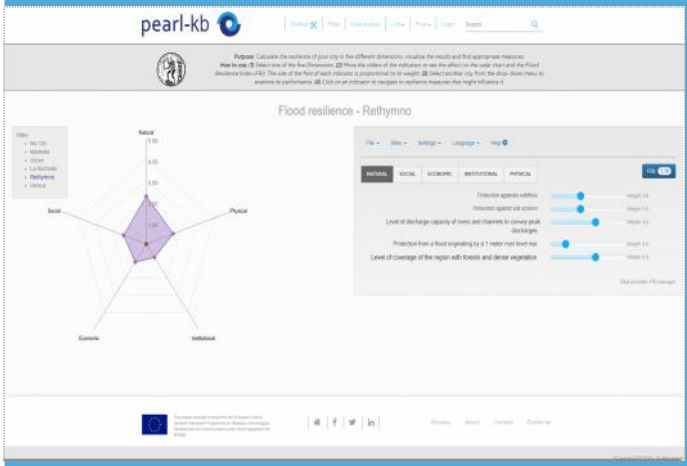
Οι δράσεις του έργου PEARL ανέδειξαν κρίσιμα σημεία των διαδικασιών λήψης απόφασης και της διακυβέρνησης όπως είναι ο πρωταγωνιστικός ρόλος της Πυροσβεστικής Υπηρεσίας κατά τη διάρκεια εξέλιξης ενός πλημμυρικού γεγονότος, αλλά και το γεγονός ότι η περιοχή μελέτης του δεν συμπεριλαμβάνεται, σύμφωνα με την Οδηγία 2007/60/ΕΚ, στις ζώνες δυνητικά υψηλού κινδύνου πλημμύρας όπως αυτές διαμορφώθηκαν κατά την προκαταρκτική αξιολόγηση. Πρόσθετα, η ελλιπής συνεργασία και συντονισμός μεταξύ φορέων και οι δυσκολίες στην κατανομή ρόλων και τα όρια των αρμοδιοτήτων έχει παρατηρηθεί ενίοτε.

Για την αντιμετώπιση των παραπάνω δυσκολιών και την ενίσχυση της διαδικασίας λήψης των αποφάσεων και της διακυβέρνησης προτάθηκαν από κοινού με τους φορείς διάφορες δράσεις. Αυτές ήταν:

- Δράση 1: **Συλλογή πληροφοριών πεδίου** από το τεχνικό προσωπικό υπηρεσιών με χρήση εφαρμογής PEARL Detective
- Δράση 2: **Συνέχεια και θεσμοθέτηση της ομάδας LAA** λειτουργώντας σαν «διεπαφή» μεταξύ φορέων και κοινωνίας ενισχύοντας διαδικασίες διαβούλευσης και την εμπλοκή των πολιτών
- Δράση 3: **Κατάστρωση σχεδίων προετοιμασίας έναντι πλημμυρών** με χρήση πλατφόρμας WebLP & αποτελεσμάτων σεναρίων
- Δράση 4: **Υπηρεσιακή χρήση και ενίσχυση δι-υπηρεσιακών συνεργασιών και συντονισμού** μέσω της πλατφόρμας WebLP
- Δράση 5: **Αναθεώρηση πολεοδομικού σχεδιασμού** λαμβάνοντας υπόψη ζώνες πλημμυρικής κατάκλυσης αξιοποιώντας την πλατφόρμα WebLP και τα προσομοιωμένα σενάρια
- Δράση 6: **Κατάστρωση προτάσεων προς χρηματοδότηση** με αξιοποίηση της Γνωσιακής Βάσης π.χ. στα πλαίσια Περιφερειακών Επιχειρησιακών Προγραμμάτων για εύρεση μέτρων αντιπλημμυρικής προστασίας συνδυαστικά με άλλες ενέργειες αναβάθμισης χώρων, μείωσης θορύβου, κ.ά.
- Δράση 7: **Ετήσια συγκέντρωση φορέων δι-υπηρεσιακής ενημέρωσης και ανταλλαγής απόψεων** σχετικά με την αντιπλημμυρική προστασία και προετοιμασία της πόλης αξιοποιώντας πιθανά το εργαλείο αξιολόγησης ανθεκτικότητας, τη γνωσιακή βάση και το ABM SAS

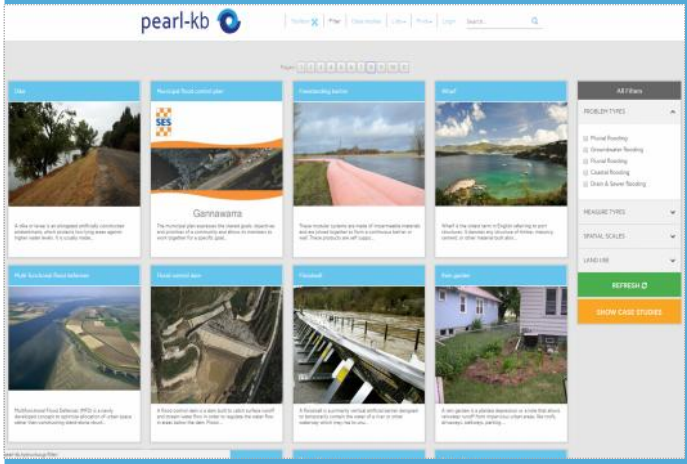
Πιθανή μελλοντική υλοποίηση των παραπάνω δράσεων πυροδότησε εποικοδομητικές συζητήσεις και προβληματισμούς. Συγκεκριμένα για τη συνέχιση της δράσης LAA, ήταν κοινά αποδεκτό ότι η θεσμοθέτηση του θα πρέπει να γίνει σε μία υπάρχουσα και εν λειτουργία δομή και συγκεκριμένα την Επιτροπή Διαβούλευσης του Δήμου. Η Πολιτική Προστασία ενδείκνυται να ηγηθεί την ανάπτυξη σχεδίων αντιπλημμυρικής προστασίας της πόλης αλλά και να οργανώνει ετήσια συνάντηση φορέων γι' αυτό το σκοπό. Τα ΦΕΚ ρεμάτων/διευθετήσεις τους και νέες προσθήκες, καθώς και ο αναθεωρημένος πολεοδομικός σχεδιασμός της πόλης μαζί με ζώνες πλημμυρικής κατάκλυσης αποτελούν αρχικά δεδομένα για ανταλλαγή και εκκίνηση συνεργασίας φορέων. Τα εργαλεία του PEARL μπορεί να αξιοποιηθούν κατά τη σύνταξη προτάσεων για υποβολή στα πλαίσια του ΕΠΠΕΡΑΑ και ΠΕΠ. Ιδιαίτερα το ABM SAS, κέντρισε το ενδιαφέρον των φορέων, αλλά χαρακτηρίστηκε αρκετά πειραματικό για την άμεση αξιοποίηση του.

ΟΜΑΔΑ ΔΡΑΣΕΩΝ 1: Ενίσχυση της διαδικασίας λήψης αποφάσεων & διακυβέρνησης



KB FRI Tool/ Εργαλείο αξιολόγησης ανθεκτικότητας

PEARL Knowledge Base / Γνωσιακή Βάση PEARL



Measures & strategies / Μέτρα & στρατηγικές

GROUP OF ACTIVITIES 2: Strengthening information & raising flood risk awareness

Protection guidelines / Οδηγίες προστασίας

Education / Εκπαίδευση

Champaign / Καμπάνια ενημέρωσης

The comprehension of social roots and causes forming and altering the flood risk of the city was of primary importance within the project. The results of research activities (e.g. the RRCA, the household survey, the vulnerability assessment, etc.), as well as the long discussions and interactions with the LAA members enabled the extraction of key points on the level of information and the citizen's awareness. Those were:

- Ignorance of city's flood risk, its management, existing flood protections measures or how they could be protected during a flood event
- Citizens' actions altering & negatively affecting the evolution of flood risk e.g. covering of drain grates to avoid malodour, illegal drop of debris in riverbeds, etc.
- Seasonality of the phenomena obstacles the initiative of implementing preparedness actions
- Individual responsibilities are not highlighted
- Citizens are not engaged at any stage of flood risk management

The solution to the aforementioned issues it is believed to be found through the implementation of the following activities.

- Action 8: **Awareness raising campaign** named **"Flood events in Rethymno: how do I alter evolution of flood risk and how to protect myself"** (through website, spots, brochures, etc.)
- Action 9: **Voluntary clean-up of a stream** and/or **drain grates** organised for the public
- Action 10: **Reforestation of burnt areas** at the upstream of the city aiming at informing the interconnection of fires with floods
- Action 11: **Raising awareness activities in schools**

Regarding the voluntary clean-up of a stream, it was raised that it is worth engaging other stakeholders too, such as the Red Cross, the local voluntary group of Scouts and the Mountaineering Group of Rethymno, since the purpose of this action is the experiential learning of multiple social groups (e.g. schools, citizens, etc.) for the consequences e.g. of waste or debris disposal in riverbeds and how this action affects flood risk.

The awareness raising campaign can be implemented by distributing information material e.g. related to Rethymno's streams, river catchments, areas at flood risk, etc. Collation of vulnerability maps, i.e. the "actual" values and the ones based on citizens' perception, might serve that purpose too.

The aim of the abovementioned actions, apart from informing and raising the awareness of citizens, is to highlight individual responsibility. Citizens actions often alter the evolution of flood risk e.g. by covering drain grates, illegal building in flood prone zones, construction of basement below sea level, drop of debris in river bed, neglect receiving measures during construction works and rain might sweep away material and block water inlets of the drainage system.

Available web-sites of authorities might also serve as additional communication tools e.g. for the dissemination of best practices and the information of Rethymno's existing flood issues and flood related infrastructure. The webpage can be further disseminated through the local press, media and the water bills of the Water Utility and its maintenance can be coordinated by Municipality's IT department.

Η κατανόηση των κοινωνικών αιτιών που επηρεάζουν τον πλημμυρικό κίνδυνο κατείχε πρωταρχικό ρόλο στις ερευνητικές δράσεις. Τα αποτελέσματα των αναλύσεων (RRCA, κατ' οίκων έρευνα, αξιολόγηση τρωτότητας, κ.ά.), καθώς και οι συζητήσεις και οι επαφές με τους φορείς έκαναν δυνατή την εξαγωγή συμπερασμάτων σχετικά με το επίπεδο ενημέρωσης και ευαισθητοποίησης των πολιτών. Αυτά ήταν:

- Έ**λλειψη γνώσης** ως προς τον πλημμυρικό κίνδυνο, τη διαχείριση και τα μέτρα που ήδη έχουν ληφθεί ή πως θα μπορούσαν εκείνοι να προστατευθούν
- **Ενέργειες που επηρεάζουν αρνητικά** στην εξέλιξη του φαινομένου π.χ. κάλυψη φρεατίων για οσμές, παράνομη ρίψη μπαζών στα ρέματα, παράνομη δόμηση/υπόγεια κ.ά.
- Η **εποχικότητα του γεγονότος** δεν επιτρέπει τη δράση τους για πρόληψη
- Δεν **εμπλέκονται σε κανένα στάδιο διαχείρισης πλημμυρών** π.χ. έστω μέσω της ενημέρωσης τους για αποφυγή στάθμευσης στους χώρους στάθμευσης του λιμανιού και δεν **αναδεικνύεται η ατομική τους ευθύνη**

Λύση στα παραπάνω ζητήματα εκτιμάται ότι θα αποτελέσει η υλοποίηση ακόλουθων δράσεων:

- Δράση 8: **Καμπάνια ενημέρωσης κατοίκων** με τίτλο **«Οι πλημμύρες στην πόλη μου: πως τις επηρεάζω και πώς να προετοιμαστώ»** (μέσω website, διαφημιστικά spot, φυλλάδια, κλπ.)
- Δράση 9: **Εθελοντικός καθαρισμός ρέματος** για το ευρύ κοινό ή/και εσχαρών εντός του αστικού ιστού
- Δράση 10: **Αναδάσωση καμένων περιοχών** ανάντη της πόλης και ενημέρωσης ως προς τη σχέση των πυρκαγιών με τις πλημμύρες
- Δράση 11: **Ενημερωτικές δράσεις σε σχολεία** σχετικά με τις Οδηγίες Προστασίας έναντι των πλημμυρών

Σχετικά με τον εθελοντικό καθαρισμό διατυπώθηκε ότι είναι σημαντική η εμπλοκή και άλλων φορέων όπως Ερυθρός Σταυρός, Πρόσκοποι, Ορειβατικός Σύλλογος Ρεθύμνου, καθώς σκοπός της δράσης είναι η βιωματική εκπαίδευση πολλαπλών κοινωνικών ομάδων (σχολεία, πολίτες, κ.ά.) για τις συνέπειες π.χ. ρίψης απορριμμάτων στα ρέματα σε σχέση με τις πλημμύρες.

Η καμπάνια ενημέρωσης μπορεί να υλοποιηθεί μέσω της διανομής πληροφοριακού υλικού απεικονίζοντας π.χ. τα ρέματα, τα όρια υδρολογικών λεκανών και τις περιοχές με αυξημένο πλημμυρικό κίνδυνο. Επίσης, μπορεί να περιλαμβάνει αντιπαραβολή χαρτών με περιοχές που θεωρούν οι κάτοικοι ότι είναι ευάλωτες, σε σχέση με εκείνες που είναι σύμφωνα με τους χάρτες τρωτότητας ή τα ιστορικά δεδομένα.

Στόχος της δράσης εκτός από την ενημέρωση και ευαισθητοποίηση των πολιτών είναι και η ανάδειξη της ατομικής ευθύνης. Πολύ συχνά ατομικές ενέργειες επηρεάζουν την εξέλιξη των πλημμυρών, π.χ. κάλυψη φρεάτων παλιάς πόλης, δόμηση σε πλημμυρικές ζώνες και κατασκευή υπογείων κάτω από τη μέση στάθμη της θάλασσας, ρίψη μπαζών, έλλειψη μέτρων προστασίας κατά την εκτέλεση χωματουργικών εργασιών, κ.ά.

Τέλος πρόσθετα επικοινωνιακά εργαλεία θα αποτελέσουν οι υφιστάμενες ιστοσελίδες των φορέων, με σκοπό π.χ. τη διάδοση βέλτιστων πρακτικών, υφιστάμενων προβλημάτων ή/και μέτρων αντιπλημμυρικής προστασίας. Η προώθησή τους μπορεί να γίνει μέσω των τοπικών ΜΜΕ ή/και των τιμολογίων της ΔΕΥΑΡ.

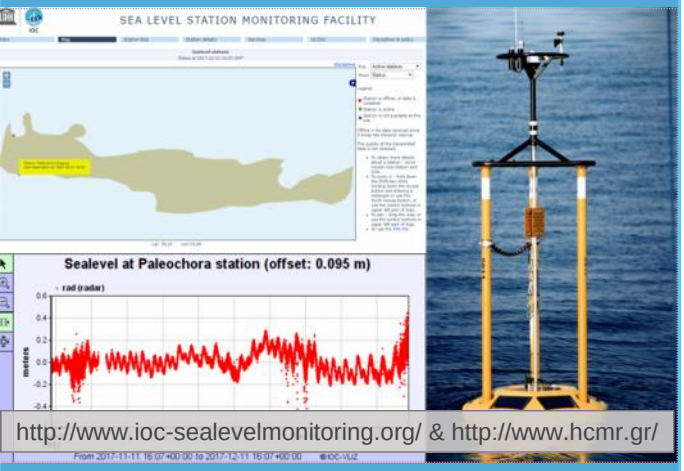
ΟΜΑΔΑ ΔΡΑΣΕΩΝ 2: Ενδυνάμωση της πληροφόρησης & ευαισθητοποίησης

Grates cleaning / Καθαρισμός εσχαρών

Voluntarism / Εθελοντισμός

Reforestation / Αναδάσωση

GROUP OF ACTIVITIES 3: Assisting in city's flood preparation and protection

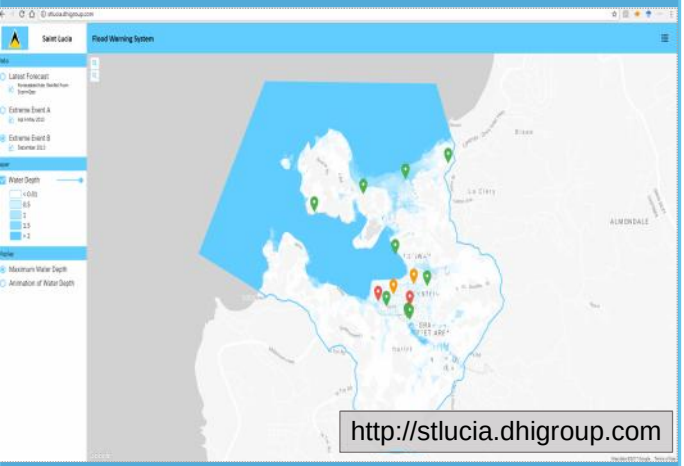


http://www.ioc-sealevelmonitoring.org/ & http://www.hcmr.gr/

SL monitoring / Παρακολούθηση ΣΘ

http://www.climatetechwiki.org

Beach nourishment / Τεχνητή αναπλήρωση ακτής



http://stlucia.dhigroup.com

EWS / Συστήματα Έγκαιρης Προειδοποίησης

After having performed several data collection activities with the stakeholders, technical meetings and literature review it was clearly understood that several significant engineering measures have already been implemented as part of the flood protection of the city e.g. flood control dams, etc. Their maintenance is of primary importance, but also difficult due to lack of funding and personnel. The transition from engineering measures to operational ones has been recognised, therefore, suggestions on future resilience measures have been focusing on non-structural interventions such as early warning systems, evacuation plans, etc. Implementation of possible future engineering measures is mostly related to the coastal zone and the port facilities. Unavailability of insurance against flood risk or compensation mechanisms from the responsible authorities is absent.

While trying to assist the existing flood preparation and protection of the city and tackle the existing flood problems, after taking into consideration different local constraints, the following measures were discussed and suggested:

- Action 12: Installation of **equipment monitoring wave height and sea level fluctuation** aiming at issuing warnings and protecting the port infrastructure
- Action 13: **Beach nourishment** tackling coastline erosion and ensuring the existence of sufficient area for wave breaking
- Action 14: Development and functioning of an **Early Warning System**
- Action 15: **Increase of height of port facilities**
- Action 16: **Construction and placement of** specially designed "covers" in the inlets of the Old Town of Rethymno, being closed in normal conditions and avoiding malodours and opening when height of water is being concentrated to allow flow towards inlets

Installation of equipment monitoring wave height and sea level fluctuation (aiming at issuing warnings and protecting the port infrastructure) was suggested to be integrated with the already implemented project of the Hellenic Centre for Marine Research if feasible. The increase of height of port facilities was not a solution commonly agreed, whereas, the construction and placement of specially designed "covers" at the inlets of the Old Town of Rethymno (as a solution for not having the drain grates covered by the citizens) received pretty positive comments so far related to their functioning and could be adopted in other locations of the city too.

It is worth mentioning that existing engineering measures have been mostly implemented to protect the Old Town of Rethymno where most of the city's activities are being located and the adjacent zones. If funding becomes available, authorities are interested in implementing engineering measures in additional streams that cross the city and the areas adjacent to Platanias river outlet which appears to be one of the areas of Rethymno under greater flood risk due to its morphology and flat, lowing terrains.

Έχοντας αναζητήσει δεδομένα με πολλαπλούς τρόπους και πηγές όπως συζητήσεις και συναντήσεις με φορείς, βιβλιογραφικές αναφορές κ.ά. έγινε σαφές ότι οι αρμόδιοι φορείς έχουν προχωρήσει σε κατασκευή αρκετών έργων μηχανικού για την αντιπλημμυρική προστασία της πόλης π.χ. 3 φράγματα ανάσχεσης πλημμυρικών ευχών κ.λπ. Η συντήρηση τους είναι σημαντική αλλά ταυτόχρονα δύσκολη λόγω έλλειψης κονδυλίων και προσωπικού. Η ανάγκη μετάβασης από τα κατασκευαστικά σε επιχειρησιακά έργα έχει αναγνωριστεί, συνεπώς, παραδείγματα μέτρων που προτάθηκαν για την αντιπλημμυρική προετοιμασία και προστασία της πόλης ήταν συστήματα έγκαιρης προειδοποίησης, σχέδια εκκένωσης κ.λπ. Πιθανά μελλοντικά έργα μηχανικού αφορούν κυρίως την παράκτια ζώνη και τις λιμενικές εγκαταστάσεις. Ακόμα, αναφέρθηκε η έλλειψη ασφάλισης έναντι πλημμυρών ή αποτελεσματικών μηχανισμών αποζημίωσης από τις αρμόδιες αρχές.

Για την ενίσχυση της υφιστάμενης αντιπλημμυρικής προετοιμασίας και προστασίας της πόλη και την επίλυση υπαρχόντων προβλημάτων, λαμβάνοντας παράλληλα υπόψη πιθανούς περιορισμούς, προτάθηκαν και συζητήθηκαν οι ακόλουθες δράσεις:

- Δράση 12: Τοποθέτηση **εξοπλισμού παρακολούθησης ύψους κύματος και μεταβολής στάθμης θάλασσας** για έγκαιρη προειδοποίηση και προστασία λιμενικών εγκαταστάσεων
- Δράση 13: **Τεχνητή αναπλήρωση ακτής** για την αντιμετώπιση της διάβρωσης και την εξασφάλιση επαρκούς ζώνης θραύσης κύματος
- Δράση 14: Δημιουργία και λειτουργία **συστήματος έγκαιρης πρόγνωσης και προειδοποίησης**
- Δράση 15: **Υπερύψωση στέψης υφιστάμενων λιμενικών εγκαταστάσεων**
- Δράση 16: **Ειδική κατασκευή και τοποθέτηση καλύμματος φρεατίων της παλιάς πόλης** για αποφυγή οσμών με ταυτόχρονη ελεύθερη ροή όμβριων υδάτων προς δίκτυο

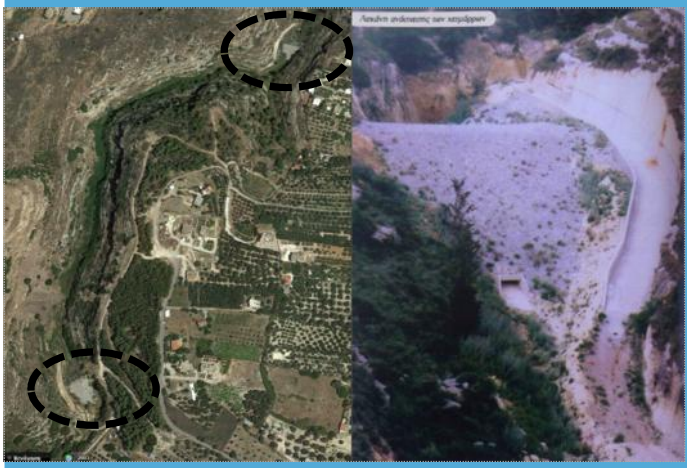
Η τοποθέτηση εξοπλισμού παρακολούθησης ύψους κύματος και διακύμανσης στάθμης θάλασσας (αποσκοπώντας στην έκδοση προειδοποιήσεων και στην προστασία των λιμενικών υποδομών) προτάθηκε να ενταχθεί, αν είναι εφικτό, με προγράμματα του Εθνικού Κέντρου Θαλασσίων Ερευνών. Η αύξηση του ύψους των λιμενικών εγκαταστάσεων δεν είναι μία πρόταση που υποστηρίχθηκε από όλους τους φορείς, ενώ η τοποθέτηση της ειδικής κατασκευής που μέχρι σήμερα έχει γίνει σε μερικά φρεάτια της παλιάς πόλης (ως μέτρο αντιμετώπισης της κάλυψής τους από κατοίκους) έλαβε θετικά σχόλια σχετικά με την μέχρι σήμερα λειτουργία της. Μάλιστα, συζητάτε η τοποθέτηση αυτών των ειδικών καλυμμάτων σε περισσότερα σημεία της πόλης.

Αξίζει να σημειωθεί ότι τα υφιστάμενα αντιπλημμυρικά μέτρα του Ρεθύμνου που έχουν υλοποιηθεί προστατεύουν κυρίως την Παλιά Πόλη, όπου οι περισσότερες λειτουργίες/δραστηριότητες της πόλης λαμβάνουν χώρα, καθώς και τις ανάντη ζώνες. Σε περίπτωση μελλοντικής εύρεσης κονδυλίων χρηματοδότησης, πρόσθετα έργα μηχανικού θα ενδιέφεραν να σχεδιαστούν και σε άλλα ρέματα της περιοχής αλλά και στις ζώνες εκατέρωθεν της κοίτης του π. Πλατανιά προς τη θάλασσα, περιοχή η οποία φαίνεται να διατρέχει σχετικά μεγαλύτερο κίνδυνο εξαιτίας της μορφολογίας της, τις ήπιες κλίσεις και τα χαμηλά της υψόμετρα.

ΟΜΑΔΑ ΔΡΑΣΕΩΝ 3: Υποστήριξη της αντιπλημμυρικής προετοιμασίας & προστασίας

Port infrastructure / Υποδομές λιμένα

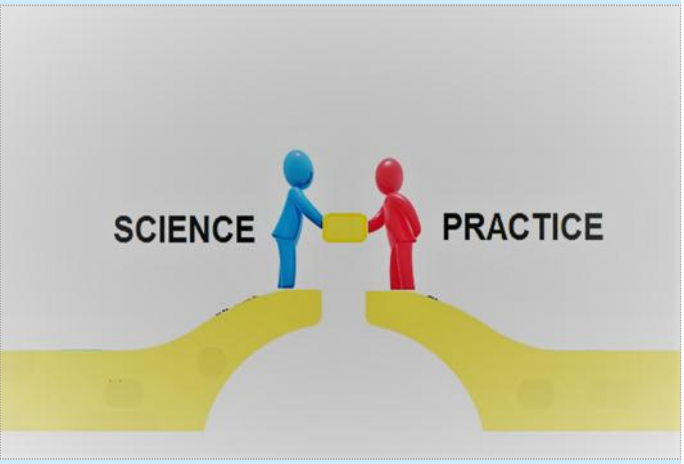
Drain grates / Εσχάρες



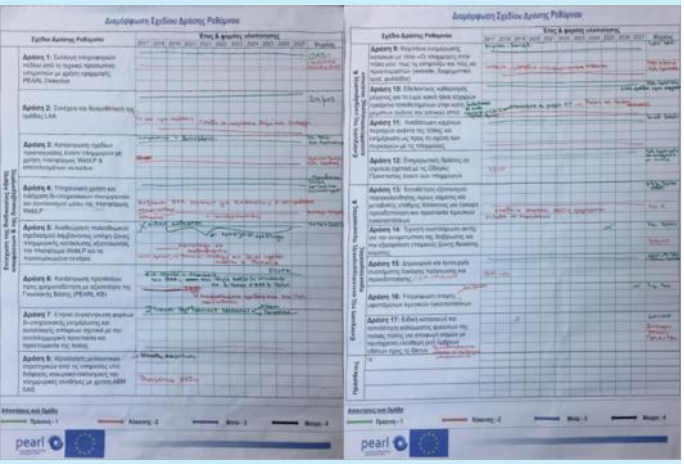
Flood dam / Φράγμα ανάσχεσης

LESSONS LEARNED, RESULTS & DISCUSSION

Strategic planning / Στρατηγικός σχεδιασμός



Bridging the gap / Γεφυρώνοντας το χάσμα



EWS / Συστήματα Έγκαιρης Προειδοποίησης

The work fulfilled in Rethymno as part of the PEARL project can be argued that is fully comprehensive and tried to meet the holistic goals set as much as possible. Moreover, it revealed the actual strengths and weaknesses of all primary aspects of flood management processes. The last and major unifying action of the PEARL work and outcomes was the development of the current actionable roadmap for the Rethymno case, a roadmap the city really needs which utilises most of the PEARL products and developed to assist flood management and decision-making processes. The suggested actions were jointly derived with the stakeholders, hence, forming the best circumstances for their actual implementation while intriguing authorities interest the most. Within scheduled activities, stakeholders were urged to look for actions which would highly strengthen city's resilience, but also activities that might be easily implemented with no need of big budget or tough restrictions imposed.

In terms of the timetable and the time horizon of when each measure could be implemented, stakeholders indicated that most of the actions do not require much effort, therefore, could be operational within the current and/or the next year. On the other hand, some activities were identified to require more time in order to be implemented (e.g. 7 to 10 years) such as the beach nourishment (an activity for tackling coastline erosion and ensuring the existence of sufficient area for wave breaking) and the increase of height of port facilities.

Since the utilisation of PEARL products was of high interest for Rethymno's Authorities, their availability on the web and their maintenance beyond the end of the projects was raised. Despite available resources of engaged partners, it was ensured that the functioning of PEARL products will be continued by utilising the infrastructure of National Research & Technology Network if needed.

Despite what the authorities of Rethymno will adopt and incorporate in their daily work eventually, the PEARL has left valuable knowledge and tools which couldn't have been obtained otherwise. But most importantly managed to provide sufficient justification on why Rethymno should be considered as an area of potential significant flood risk (APSFR) within the EU Flood Directive work, hence, gave the chance to Rethymno's authorities to be eligible and able to apply for future funding which will enable them to implement new measures and actually increase city's flood resilience. Moreover, all stakeholder groups commonly agreed to utilise the experience from the LAA initiative. LAA was proved to be a valuable experience of participation procedure and knowledge exchanging. To this term PEARL achieved to promote the idea of public consultation and common agreement in decision-making procedures, among the different levels of hierarchy and different social groups regarding flood risk management and in this way to move forward the need for flood risk governance strengthening in Rethymno. The LAA group which was established under the PEARL framework is possible to continue to work as part of Consultation Committee of Rethymno's Municipality.

For Rethymno, the good co-operation between the involved research partners and Rethymno's stakeholders has to be highlighted in this regard. Therefore, engaging stakeholders was one of the key lessons learned which could certainly help bridging the gap between research and practice and promote best flood management practices.

Οι εργασίες που εκπονήθηκαν στο Ρέθυμνο στα πλαίσια του ερευνητικού έργου PEARL μπορεί να υποστηριχθεί ότι παρείχαν μία ολοκληρωμένη προσέγγιση για τη διαχείριση του φαινομένου των πλημμυρών. Πρόσθετα ανέδειξε τα δυνατά σημεία αλλά και τις αδυναμίες πολλών πτυχών και σταδίων της διαχείρισης των πλημμυρικών κινδύνων. Η τελευταία και συνδυαστική δράση του έργου και των επιμέρους αποτελεσμάτων ήταν η ανάπτυξη του τρέχοντος σχεδίου δράσης της πόλης του Ρεθύμνου, ένα σχέδιο δράσης που πραγματικά χρειάζεται η πόλη, ενώ παράλληλα προσπαθεί να αξιοποιήσει τα προϊόντα του έργου που αναπτύχθηκαν να βοηθήσουν αυτό το σκοπό. Οι δράσεις που προτάθηκαν, αναδείχθηκαν από κοινού με τους φορείς, δημιουργώντας συνεπώς τις καταλληλότερες συνθήκες για την πραγματική υλοποίηση τους στο μέλλον, κεντρίζοντας παράλληλα το ενδιαφέρον των αρμόδιων φορέων. Στα πλαίσια των συμμετοχικών δράσεων, από όπου προέκυψαν και τα προτεινόμενα μέτρα, οι φορείς παροτρύνθηκαν να αναζητήσουν λύσεις που θα αύξαναν την ανθεκτικότητα της πόλης έναντι των πλημμυρών αλλά παράλληλα θα ήταν και εύκολα εφαρμόσιμες χωρίς μεγάλες απαιτήσεις σε κονδύλια ή περιορισμούς.

Όσον αφορά το χρονοδιάγραμμα υλοποίησης των δράσεων, σύμφωνα με τους φορείς είναι άμεσα εφαρμόσιμες, στο τρέχον ή το επόμενο έτος. Μόνο οι δράσεις της τεχνητής αναπλήρωσης ακτής (για την αντιμετώπιση της διάβρωσης και την εξασφάλιση ζώνης θραύσης κύματος) και της αύξησης ύψους υφιστάμενων λιμενικών εγκαταστάσεων εκτιμάται ότι απαιτεί χρονικό ορίζοντα π.χ. 7 με 10 χρόνια.

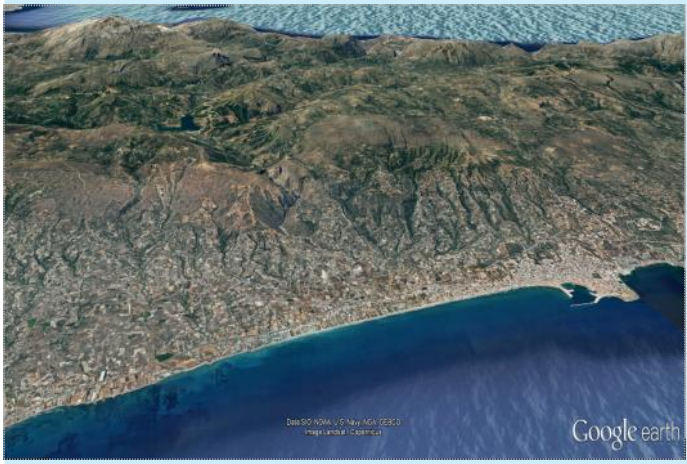
Το ενδιαφέρον των φορέων ως προς τα διαδικτυακά εργαλεία του PEARL και την πιθανή αξιοποίηση τους έπειτα τη λήξη του έργου αποτέλεσε πρόσθετο αντικείμενο συζήτησης. Παρά τους διαθέσιμους πόρους των συνεργαζόμενων φορέων του έργου, προτάθηκε η διασφάλιση της λειτουργίας των προϊόντων με χρήση των υποδομών του Εθνικού Δικτύου Έρευνας & Τεχνολογίας Α.Ε. εάν χρειαστεί.

Πέρα από τι θα επιλεγεί τελικά να αξιοποιηθεί από τους φορείς του Ρεθύμνου, το έργο ανέπτυξε σημαντική γνώση και εργαλεία τα οποία δεν θα ήταν εφικτό να παραχθούν διαφορετικά. Το πιο σημαντικό όμως είναι ότι μέσα από το έργο προτάθηκε επίσημα η ενσωμάτωση της πόλης του Ρεθύμνου στις ζώνες δυνητικά υψηλού κινδύνου πλημμύρας (ΖΔΥΚΠ) σύμφωνα με την Οδηγία 2007/60/ΕΚ, δίνοντας έτσι τη δυνατότητα στους φορείς να μπορούν να αιτηθούν στο μέλλον για πρόσθετη χρηματοδότηση με σκοπό την υλοποίηση αντιπλημμυρικών υποδομών. Επίσης, αναγνωρίστηκε η χρησιμότητα της LAA πρωτοβουλίας σαν κομμάτι των συμμετοχικών διαδικασιών και της ανταλλαγής γνώσης. Με τον τρόπο αυτό, το PEARL πέτυχε να προωθήσει την ιδέα της διαβούλευσης και ανταλλαγής γνώσης στις διαδικασίες λήψης αποφάσεων μεταξύ των διαφόρων επιπέδων ιεραρχίας και διαφόρων κοινωνικών ομάδων σχετικά με τη διαχείριση των κινδύνων πλημμύρας, προωθώντας την ανάγκη ενίσχυσης της διακυβέρνησης του κινδύνου των πλημμυρών στο Ρέθυμνο. Η συνέχιση της λειτουργίας της ομάδας LAA θα μπορέσει να διασφαλιστεί με ενσωμάτωσή της στην Επιτροπή Διαβούλευσης του Δήμου.

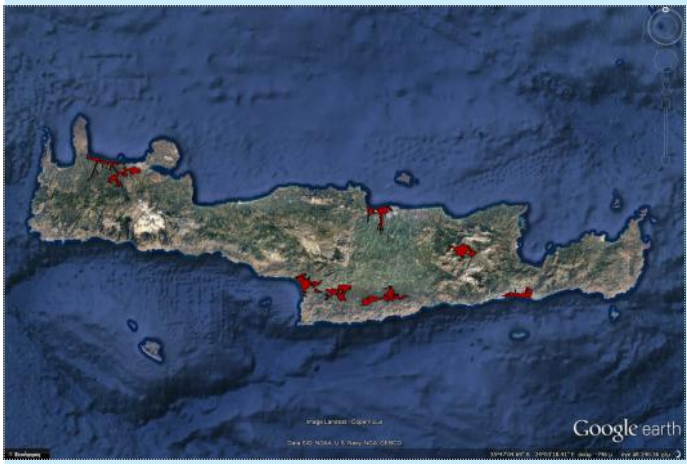
Για το Ρέθυμνο, πρέπει να τονιστεί η καλή και στενή συνεργασία μεταξύ των ερευνητών και των φορέων, η οποία δίδαξε ότι θα μπορούσε σίγουρα να βοηθήσει στη γεφύρωση του χάσματος μεταξύ έρευνας και πρακτικής και να προωθηθούν οι καλύτερες πρακτικές στη διαχείριση των πλημμυρών σε τοπικό επίπεδο.

ΔΙΔΑΓΜΑΤΑ, ΑΠΟΤΕΛΕΣΜΑΤΑ & ΣΥΖΗΤΗΣΗ

Port infrastructure / Υποδομές λιμένα

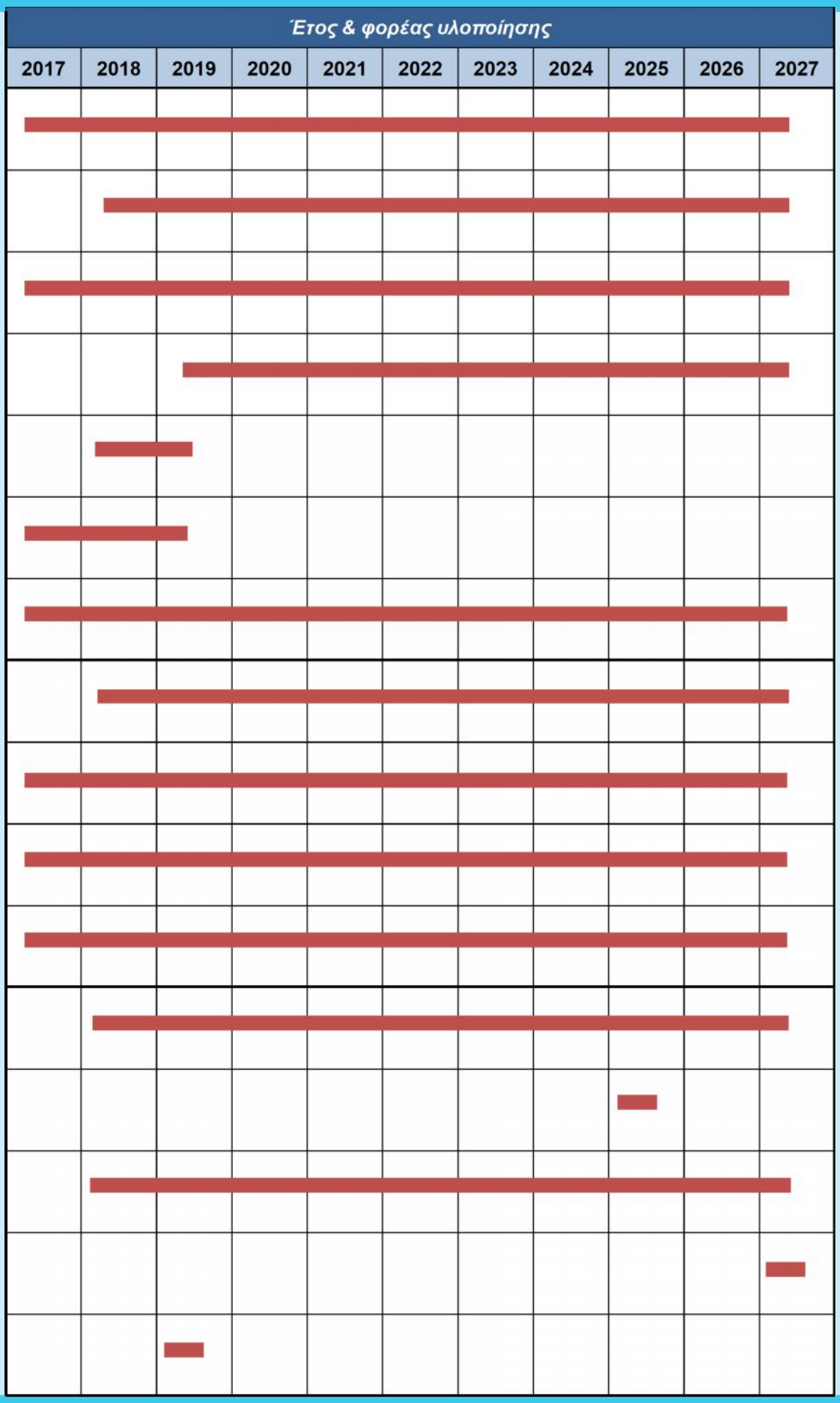


Drain grates / Εσχάρες



Crete's APSFR / ΖΔΥΚΠ Κρήτης

Σχέδιο Δράσης Ρεθύμνου		
Άξονες / Δράσεις ανά άξονα	Ενίσχυσης της διαδικασίας λήψης αποφάσεων & της διακυβέρνησης	**Δράση 1:** Συλλογή πληροφοριών πεδίου από το τεχνικό προσωπικό υπηρεσιών με χρήση εφαρμογής PEARL Detective **Action 1:** Collection of flood reports from the field by the technical department of authorities by using the PEARL detective
		Δράση 2: Συνέχεια και θεσμοθέτηση της ομάδας LAA λειτουργώντας σαν «διεπαφή» μεταξύ φορέων και κοινωνίας ενισχύοντας διαδικασίες διαβούλευσης και την εμπλοκή των πολιτών **Action 2:** Continuation of the LAA and its official establishment under an existing authority serving as an interface between authorities and society
		Δράση 3: Κατάστρωση σχεδίων προετοιμασίας ένανπι πλημμυρών με χρήση πλατφόρμας WebLP & αποτελεσμάτων σεναρίων **Action 3:** Development of flood protection plans by using the WebLP, the uploaded scenarios & results
		Δράση 4: Υπηρεσιακή χρήση και ενίσχυση δι-υπηρεσιακών συνεργασιών και συντονισμού μέσω της πλατφόρμας WebLP **Action 4:** Official use (by each authority) and strengthening of multi-agency collaboration & coordination by using the WebLP
		Δράση 5: Αναθεώρηση πολεοδομικού σχεδιασμού λαμβάνοντας υπόψη ζώνες πλημμυρικής κατάκλυσης αξιοποιώντας την πλατφόρμα WebLP και τα προσομοιωμένα σενάρια **Action 5:** Revision of urban planning by taking into consideration flood zones by using the WebLP and the simulated scenarios
		Δράση 6: Κατάστρωση προτάσεων προς χρηματοδότηση με αξιοποίηση της Γνωσιακής Βάσης π.χ. στα πλαίσια Περιφερειακών Επιχειρησιακών Προγραμμάτων για εύρεση μέτρων ανπιπλημμυρικής προστασίας συνδυαστικά με άλλες ενέργειες αναβάθμισης χώρων, μείωσης θορύβου, κ.ά. **Action 6:** Drafting of new proposal requesting funding by using the PEARL KB e.g. in the framework of Regional Operational Programs for finding flood control measures combined with other actions aiming at aesthetically upgrading areas, lessening of noise level, etc.
		Δράση 7: Ετήσια συγκέντρωση φορέων δι-υπηρεσιακής ενημέρωσης και ανταλλαγής απόψεων σχετικά με την ανπιπλημμυρική προστασία και προετοιμασία της πόλης αξιοποιώντας πιθανά το εργαλείο αξιολόγησης ανθεκτικότητας, τη γνωσιακή βάση και το ABM SAS **Action 7**: Annual meeting of authorities for knowledge exchange & update related to the flood preparation and protection of the city while utilising the online FRI tool, the KB and the ABM SAS
	Ενίσχυσης της ενημέρωσης & ευαισθητοποίησης πολιτών	**Δράση 8:** Καμπάνια ενημέρωσης κατοίκων με τίτλο «Οι πλημμύρες στην πόλη μου: πως τις επηρεάζω και πώς να προετοιμαστώ» (μέσω website, διαφημιστικά spot, φυλλάδια, κλπ.) **Action 8:** Awareness raising campaign named "Flood events in Rethymno: how do I alter evolution of flood risk and how to protect myself" (through website, spots, brochures, etc.)
		Δράση 9: Εθελοντικός καθαρισμός ρέματος για το ευρύ κοινό ή/και εσχαρών εντός του αστικού ιστού **Action 9:** Voluntary clean-up of a stream and/or drain grates organised for the public
		Δράση 10: Αναδάσωση καμένων περιοχών ανάντη της πόλης και ενημέρωσης ως προς τη σχέση των πυρκαγιών με τις πλημμύρες **Action 10:** Reforestation of burnt areas at the upstream of the city aiming at informing the interconnection of fires with floods
		Δράση 11: Ενημερωτικές δράσεις σε σχολεία σχετικά με τις Οδηγίες Προστασίας ένανπι των πλημμυρών **Action 11:** Raising awareness activities in schools
	Ενίσχυσης της ανπιπλημμυρικής προστασίας & προετοιμασίας	**Δράση 12:** Τοποθέτηση εξοπλισμού παρακολούθησης ύψους κύματος και μεταβολής στάθμης θάλασσας για έγκαιρη προειδοποίηση και προστασία λιμενικών εγκαταστάσεων **Action 12:** Installation of equipment monitoring wave height and sea level fluctuation aiming at issuing warnings and protecting the port infrastructure
		Δράση 13: Τεχνητή αναπλήρωση ακτής για την αντιμετώπιση της διάβρωσης και την εξασφάλιση επαρκούς ζώνης θραύσης κύματος **Action 13:** Beach nourishment tackling coastline erosion and ensuring the existence of sufficient area for wave breaking
		Δράση 14: Δημιουργία και λειτουργία συστήματος έγκαιρης πρόγνωσης και προειδοποίησης **Action 14:** Development and functioning of an Early Warning System
		Δράση 15: Υπερύψωση στέψης υφιστάμενων λιμενικών εγκαταστάσεων **Action 15:** Increase of height of port facilities
		Δράση 16: Ειδική κατασκευή και τοποθέτηση καλύμματος φρεατίων της παλιάς πόλης για αποφυγή οσμών με ταυτόχρονη ελεύθερη ροή όμβριων υδάτων προς δίκτυο **Action 16:** Construction and placement of specially designed "covers" in the inlets of the Old Town of Rethymno, being closed in normal conditions and avoiding malodours and opening when height of water is being concentrated to allow flow towards inlets


Έτος & φορέας υλοποίησης
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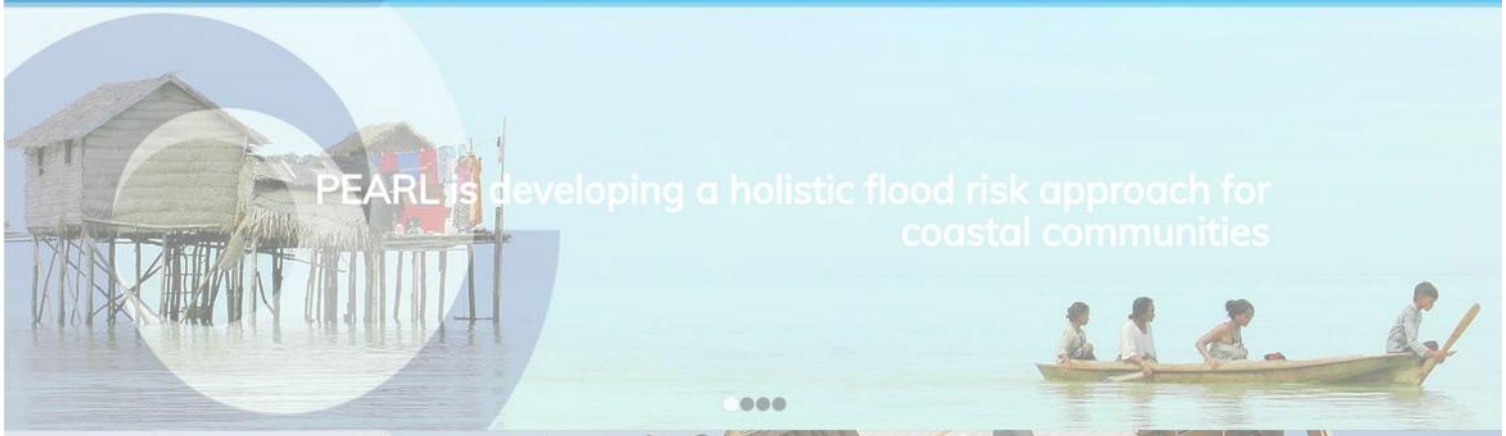
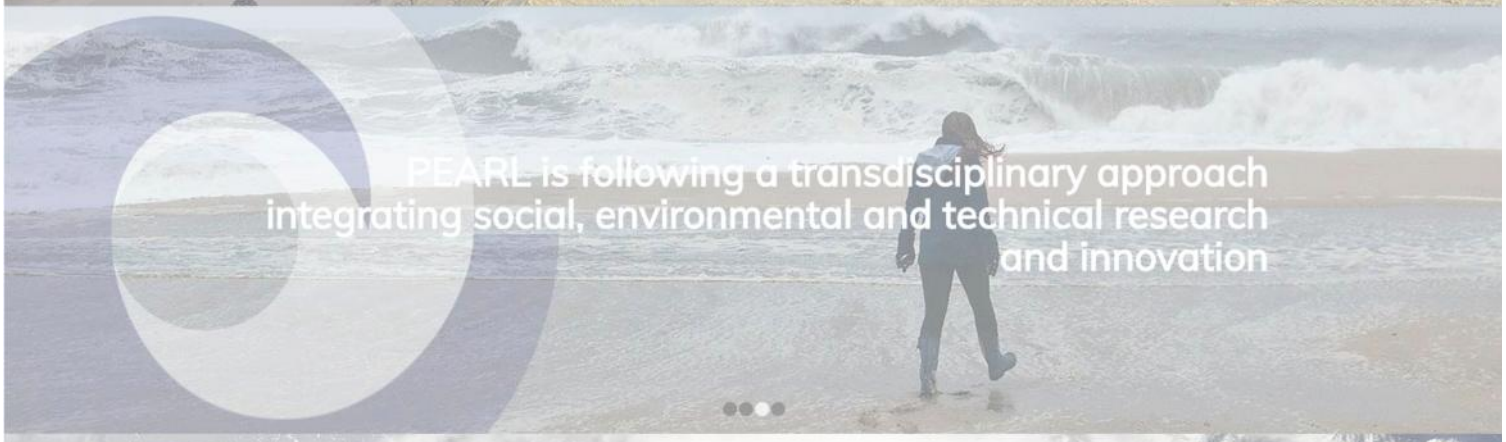
Preparing for Extreme And Rare events in coastaL regions

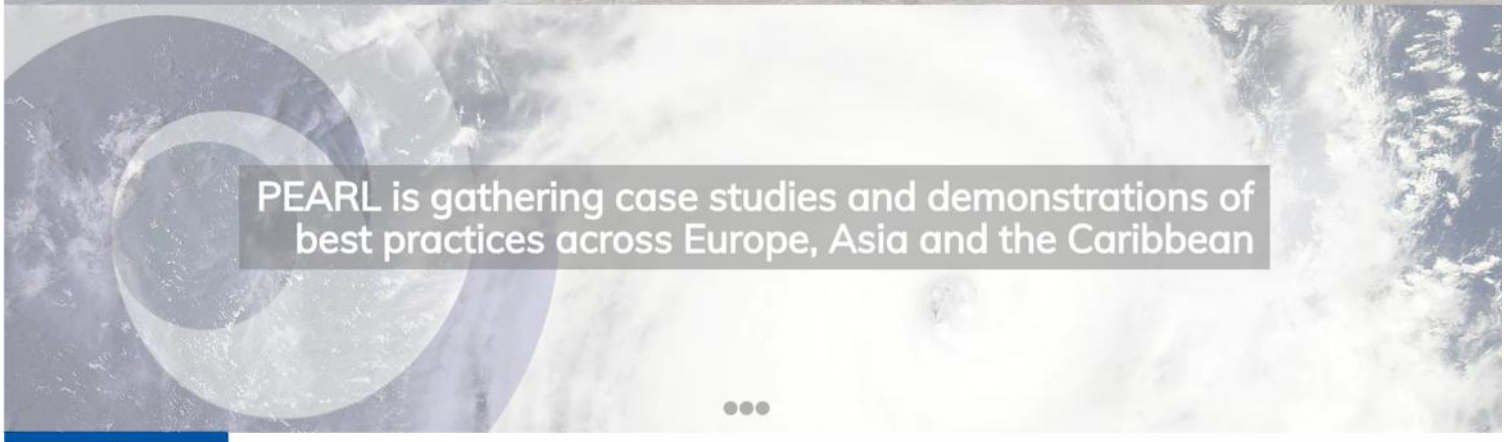


PEARL is developing a holistic flood risk approach for coastal communities

PEARL is improving forecasting, prediction and early warning capabilities



PEARL is following a transdisciplinary approach integrating social, environmental and technical research and innovation



PEARL is gathering case studies and demonstrations of best practices across Europe, Asia and the Caribbean

References

Asyhari, A. (2017). Flood Damage Modelling Towards Climate Change Adaptation to Flood Risk in a Coastal City. Master thesis, Master Programme in Flood Risk Management, Technical University of Dresden, Germany and UNESCO-IHE, Institute for Water Education, Delft, the Netherlands.

Berbel Roman, S. (2014). Modelling flooding from the sea interacting with the drainage system under the influence of combined flood hazards to develop risk management strategies for the coastal region of Greve, Denmark. Master thesis, Hydroinformatics and Water Engineering, Ecole Polytechnique Universitaire, Universite de Nice-Sophia Antipolis, France.

Braaker, H; Ollroge, D.: Der Sturmflutschutz im Hafen Hamburg nach der Sturmflut vom 3. Januar 1976 – III. Konstruktion und Ausführungsbeispiele des privaten Hochwasserschutzes, In: Jahrbuch der Hafentechnischen Gesellschaft, Vol. 37, pp. 235-255, Springer-Verlag, 1980, In: Philipp, J.: Summary of the development of coastal and flood protection measures of the Elbe estuary, Project work, 79 pages, 2015 (In German)

Colding, A. (1881) Nogle Undersøgelser over Stormen over Nord- og Mellem-Europa af 12te-14de November 1872 og den derved fremkaldte vandflod i Østersøen, Vidensk. Selsk. Skr., 6. Række, Naturvidenskabelig og Matematisk Afdeling I4.

European Commission (2009). The economics of climate change adaptation in EU coastal areas. Country Reports: Denmark. Executed by Policy Research Corporation (in association with MRAG). Retrieved from http://ec.europa.eu/maritimeaffairs/documentation/studies/climate_change_en.

Faccini F, Luino F, Sacchini A, Turconi L (2015) Flash Flood Events and Urban Development in Genoa (Italy): Lost in Translation. In: Engineering Geology for Society and Territory - Volume 5 (G. Lollino et al. eds.), Springer International Publishing Switzerland 2015, pp 797-801. https://doi.org/10.1007/978-3-319-09048-1_155

Faccini F, Paliaga G, Piana P, Sacchini A, Watkins C (2016) The Bisagno stream catchment (Genoa, Italy) and its major floods (1822, 1970 and 2014): geomorphic and land use variations in the last three centuries. Geomorphology, 273: 14-27. https://doi.org/ 10.1016/j.geomorph.2016.07.037

Free and Hanseatic City of Hamburg: Die große Flut in Hamburg – Eine Chronik der Kata strophe vom Februar 1962, School authority, 1962 (In German)

Fröhle, P., Gruhn, A. and Salecker, D. (2014): Final Report HoRisK B (03KIS079) Loads on coastal protection structures and consequences of failure in the Baltic Sea region, 173p.

Genest, C., Favre, A.-C. (2007): Everything you always wanted to know about copula modeling but were afraid to ask, In: Journal of Hydraulic Engineering, 12, pp. 347-368

Greve Kommune (2007). Oversvømmelserne i Greve Kommune Juli 2007. Technical report. Retrieved from http://www.gsforsyning.dk/sites/default/files/oversvommelserne_i_greve_kommune_juli_2007.pdf

Heerten, G.; Partenscky, H.-W.: Ein Vergleich der Sturmflut vom 3. Januar 1976 auf der Elbe mit den anderen Sturmfluten nach 1962, In: Mitteilungen des Franzius-Instituts für Wasserbau und Küsteningenieurwesen der Technischen Universität Hannover, Vol. 45, pp. 222-324, In-house publishing of the Franzius-Institut für Wasserbau und Küsteningenieurwesen der Technischen Universität Hannover, 1977 (In German)

Hötte, H., et.al.: Die Große Flut – Katastrophe Herausforderungen Perspektiven, edt.: Hötte, H. Accompanying book of the exhebition in the Hamburg Town Hall (50. Anniversary of the storm surge 1962), Landeszentrale für politische Bildung, ISBN: 978-3-929728-72-9

Kelder, T. (2011). Flood action plan of Greve. Retrieved from http://www.eukn.eu/e-library/project/bericht/detail/flood-action-plan-of-greve/.

Kramer, J.; Rohde, H.: Historischer Küstenschutz, Deichbau, Inselschutz und Binnenentwässerung an Nord- und Ostsee, Verlag Konrad Wittwer, 1992, In: Philipp, J.: Summary of the development of coastal and flood protection measures of the Elbe estuary, Project work, 79 pages, 2015 (In German)

Laucht, H.: Der Sturmflutschutz im Hafen Hamburg nach der Sturmflut vom 3. Januar 1976, In: Jahrbuch der Hafentechnischen Gesellschaft, Vol. 36, pp. 157-171, Springer- Verlag, 1977/1978

Lecture Notes: Maintenance and Defence of Flood Protection Structures, Lecturer: Dr.-Ing. Olaf Müller, Summer Semester 2016, 2016

LSBG: Landesbetrieb Straßen, Brücken und Gewässer: Die Sturmflut nach dem Tief Xaver vom 5. Bis 7. Dezember 2013, Report Nr. 16/2014 (In German)

LSBG: Landesbetrieb Straßen, Brücken und Gewässer: Gewässer und Hochwasserschutz in Zahlen, Report Nr. 14/2012, 2012 (In German)

LSBG: Landsbetrieb Straßen, Brücken und Gewässer: Sturmflutschutz in Hamburg Gestern-Heute-Morgen, Report Nr. 10/2012, 2012 (In German)

Madsen, H. (2008). Vandstandsstatistik i Køge Bugt under klimaændringer. Report by DHI for Greve Kommune. Retrieved from http://www.greveforsyning.dk/dokumenter/Klima/Vandstandsstatistik%20i%20K%C3%B8ge%20Bugt%20under%20klima%C3%A6ndringer%20dec08.pdf.

Müller-Navarra, S.H.; Bork, I.: Entwicklung eines operationellen Tideelbemodells auf der Ba sis des hydrodynamischen-numerischen Modellverfahrens BSHcmod für die Nord-und Ostsee, In: Die Küste 79, pp. 81-123

PEARL (2016). D4.1 Report: Online Modelling Tools and Techniques for Early Warning Systems.

PEARL (2016). Integrated modelling framework for hazard assessment in coastal regions

PEARL (2017a). D4.2 Report: Guidelines on Achieving Faster Simulations for Early Warning.

PEARL (2017b). D4.3 Report: Guidelines for Uncertainty Propagation Analysis.

PEARL (2017c). D2.4 Report: A report describing the effectiveness of integrated modelling/hazard assessment framework performed in the case study work.

Roediger, G.: Entwicklung und Verlauf der Wetterlage vom 16./17. Februar 1962, In: Die Küste – Archiv für Forschung und Technik an der Nord- und Ostsee, Vol. 10, Issue 1, pp. 1-5, 1962

Salecker, D.; Schlamkow, Ch.; Gruhn, A.; Fröhle, P.: Parameterization of storm surge hydrographs using univariate and bivariate statistical models, In: Proceedings of the 8th International Conference on Coastal and Port Engineering in Developing Coun-tries, Copedec 2012, IIT Madras, Chennai, ISBN: 978-93-80689-06-7, 2012

Shaikh, S.; Gerschivic, I.; Manojlovic, N.; Nehlsen, E.; Gruhn,A.; Fröhel, P.: An operational hydrodynamic-numerical model of the Elbe estuary with Telemac 2D based on predicted water levels, 12th International Conference on Hydroscience & Engineering – Hydro-Science and Engineering for Environmental Resilience, Tainan, Taiwan, 2016

Sto. Domingo, N. D., Paludan,B., Hansen, F., Madsen, H., Sunyer, M., Mark, O. (2010). Modeling of sea level rise and subsequent urban flooding due to climate changes. In E. &. DHI Water (Ed.), SimHydro 2010: Hydraulic modeling and uncertainty, (p. 9). Sophia Antipolis.

Vestergaard, L. F. (2011). Analyse af oversvømmeslesmønstret ved havvandsstigning i Køge Bugt ud for Greve. Note to agenda item for meeting in 'Teknik og Miljøudvalget', Copenhagen Municipality. Retrieved from http://www.gsforsyning.dk/sites/default/files/havstrategi_politiskvedtaegt_bilag.pdf.