consorseguros REVISTA DIGITAL

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Number 12 | Spring 2020

The importance of prevention

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Summary

Editors Board

The Consorcio de Compensación de Seguros digital magazine "Consorseguros" (CCS) is published every six months, its content particularly addressing matters related to the Consorcio's activities in various fields of insurance, reflecting on and analysing them.

NIPO: 094-20-094-2

Editorial

We have already been working on prevention for several years but perhaps, given that in the last few months of 2019 and those coming into this year we have had to cope with a great many losses from natural events, such as the major low-pressure areas that have caused huge floods, the need for prevention has been put into even sharper perspective. This is why we are devoting this, the twelfth edition of our digital magazine, to "The importance of prevention".

With respect to floods and other natural hazards covered by extraordinary risk insurance, Spain's system is well-equipped to respond to loss events of this kind and also to adapt and evolve. Despite this, in a context where it appears that the effects of climate change are set to become increasingly conspicuous, in order to be in a position to be able to control risk within insurable parameters, even when these extraordinary risk insurance parameters have already been set at an extremely high level relative to other schemes, the other components of risk will also have to be addressed, such as exposure and vulnerability, which essentially means prevention.

Over the past months natural disaster threats, which are only too familiar due to their greater intensity and frequency, have manifested themselves in the form of an almost uninterrupted stream of bouts of deep atmospheric convection, with heavy, highly-localised cloudbursts entailing flash-floods, as well as low-pressure areas and cut-off lows. The consequences of these have had the common denominator of a hotter sea and a higher level, which have in turn triggered both wider and heavier rainfalls, along with the floods they bring, and coastal phenomena such as extremely serious floods and wave battering.

These cases serve to illustrate the crucial nature of the prevention to which we have alluded in the first instance.

With respect to floods and other natural hazards covered by extraordinary risk insurance, Spain's system is well-equipped to respond to loss events of this kind and also to adapt and evolve. Despite this, in a context where it appears that the effects of climate change are set to become increasingly conspicuous, in order to be in a position to be able to control risk within insurable parameters, even when these extraordinary risk insurance parameters have already been set at an extremely high level relative to other schemes, the other components of risk will also have to be addressed, such as exposure and vulnerability, which essentially means prevention.

As regards this subject, this edition does not come with a front-page story, but instead with five, which complement each other and tackle the issue of prevention from several different standpoints.

River and rain flood prevention is examined in two contributions: one by the Directorate General for Water (DGA for the Spanish) and Tragsatec, which explains various cases of applying cost-benefit studies to damage reduction and in certain respects represents putting into practice the "Guide to reducing building vulnerability to flooding" published by the DGA and the Consorcio de Compensación de Seguros (CCS) in 2017.

The other contribution, written by the Waters Commission of the Ebro River Basin Authority, offers a detailed explanation of the actions being taken within the Ebro Resilience programme to reduce the impact of river floods. These use a different approach to that which has normally been pursued, by combining defence measures with others designed to foster controlled flooding in zones unexposed to this risk and which allow river courses more space for the natural processes to take place when their water-level rises, reducing in turn risk along the more exposed stretches.

From the Sub-Directorate General for Coastal Protection of the Directorate General for the Coast and Sea, which, as with the contributors of the previous two articles, operates within the Ministry for the Ecological Transition and the Demographic Challenge, we include an article on coastal floods, the foreseeable effects of climate change and the studies underway to assess them, as well as possible adaptation and damage-reduction measures and, basically, those to protect such a delicate environment that is so harshly subjected to all manner of pressures as the coastline.

The other two articles hail from the corporate world and relate to projects on which the CCS is, or has been, involved in some way.

The company Cetaqua has been working hard on developing flood damage curves which enable estimates to be made of the cost of flooding with respect to different types of risks and which can be applied to both modelling damage and evaluating potential prevention measures based (as in the first article mentioned) on cost-benefit studies. The data used is for losses insured by the CCS.

The other article is from environmental consultancy Icatalist and describes one of the more interesting projects that have been carried out on a Europe-wide level to assess the impact of nature-based solutions to prevent hydrological risks: “NAIAD”. The project has gradually morphed into a platform for technical and scientific bodies, as well as the local and insurance sectors, to use as a meeting-point. The article describes several protection solutions within different fields of work on the project and introduces the concept of a natural insurance programme that uses the insurance value of ecosystems to protect against the losses caused by catastrophes, and therefore for prevention.

That all said, right in the middle of preparing this edition of Consorseguros Digital the global pandemic has broken out involving the coronavirus, which manifests itself in the disease known as COVID-19. This has become a key part of our lives and preventive measures have been taken to stop it spreading: from the lockdown for our own safety to implementation of strict hygiene and social-distancing protocols. We therefore wanted to include a review of an OECD report on pandemics, insurance and the potential insurance response to threats of this kind.

Thus in the “News” section, and from the standpoint of the CCS, we also wanted to review a series of extremely significant loss events that began last summer and ran on until January 2020, which were in turn almost immediately followed by the COVID-19 crisis and the implementation of a raft of measures on the part of the CCS to ensure the continuity of its activities, as well as to reinforce support for Spain’s insured by our organisation.

As is customary, the magazine ends with a review of jurisprudence which, in this case again focusses on an increasingly important issue: the concept of a traffic event and its far-reaching implications for motor car third party liability insurance.

To close we would like to make one very important point. This magazine is a joint effort in which many people participate unselfishly. To both the contributors, who are prestigious professionals that devote a considerable amount of their time to writing and then reviewing their pieces, and the employees of the CCS who collaborate in putting together the magazine, we offer our heartfelt acknowledgement and thanks.

Prevention, protection, preparation and repair: measures to reduce flood risk along the axis of the Ebro

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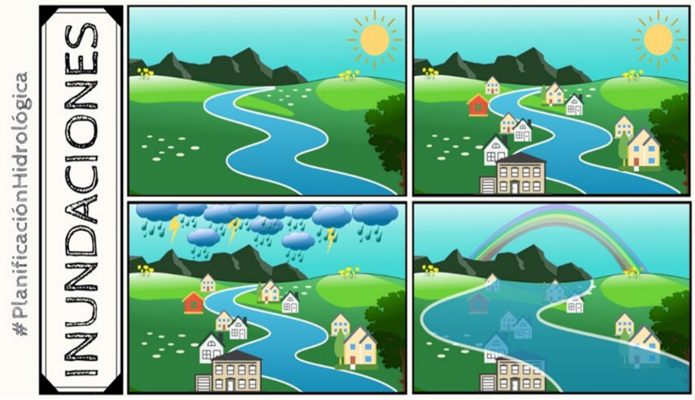
Waters Commission, Ebro Basin Authority

Society as a whole (victims, the authorities, associations, etc.) shares the same goal as regards floods: Keeping down the loss and harm to property and, above all, to people. On the middle stretch of the Ebro, the recurrence of the flooding phenomenon and the economic and social impact of water level rises set the river basin authority to work in its quest for innovative action to curb the adverse effect of flooding a long time ago.

There are two pillars here: The first one is coordination. This entails joint work that has prompted definition of the Ebro Resilience Strategy and has brought together the Ministry for the Ecological Transition and the Demographic Challenge, the Ebro Basin Authority and the regional governments of La Rioja, Navarre and Aragon, while including the direct participation of local institutions in the search for a consensus among affected, associations and academia.

The second one is the pursuit of new approaches to what is a complex problem and an inevitable natural phenomenon. This calls for combined efforts to diminish its negative effects. There is no single or definitive solution and everything done in the past has led towards seeking a necessary change of model to achieve different results.



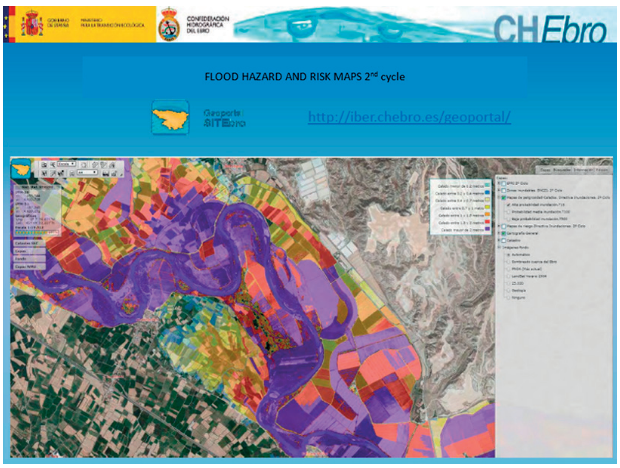
On the other hand, Ebro Resilience means implementing the Flood Risk Management Plan (FRMP) for the Ebro Area (PGRIEbro for the Spanish) on the middle section of the river, and consequently also the lines marked out by the European Union via its Floods Directive, where the PGRIEbro represents the third and final phase of its implementation.

The previous phases of implementation of Directive 2007/60 initially consist of performing the preliminary flood risk assessment (the PFRA) for each hydrographic basin and pinpointing the *Areas with a Potentially Significant Risk of Flooding (APSRF)*, and then secondly, acquiring knowledge of the extent of floods under various different probability scenarios by producing Flood Hazard and Risk Maps.

For its part, the FRMP for the Ebro Area (PGRIEbro), the third phase of the Directive, is intended to raise awareness of flood risk and promote self-protection among the population and both social and economic actors; make territorial planning adequate; improve predictive capacity; strengthen coordination among public administrations; reduce the vulnerability of exposed elements; lessen the hazardousness of flooding, and upgrade the condition of water bodies.

We are currently at the second phase of the second cycle (each cycle comprises the three phases referred to, which are reviewed every six years) of flood risk planning in which the new hazard and risk mapping has been submitted to public consultation. We shall soon move on to the third phase of the second cycle, which entails a review of the FRMP from the first cycle.

Within the Ebro river basin some 1,721 km of rivers have been defined as APSFRs, which were identified in the PFRA as those stretches of river where the flood risk is greatest, i.e. where the loss from flooding may be highest. The entire mid-section of the Ebro is an APSFR.



Hazard and risk maps have been made for over 4,000 km of rivers and they examine three separate return periods or possible scenarios: high, medium or low flood frequencies. These are respectively associated with a statistical likelihood of occurrence every 10, 100 or 500 years. These maps will be fed into the National

Flood Zone Mapping System (SNCZI for the Spanish) and are accessible for all government bodies and individuals using our "SITEbro" map viewer, representing a publicly available tool for decision-making.

In this second cycle, the Ebro Basin Authority has decided to give greater prominence to the data from the gauging stations, given that this provides a better knowledge and a data series that is six years longer than in the initial cycle, where it had already been indirectly taken into account, since the CAUMAX application was used to find the flows studied (CAUMAX being the map of maximum flow volumes in Spain which was charted by "CEDEX", the Centre for Studies and Experimentation of Public Works, in 2011 when they were calculated using a natural system and measured using gauging stations).

Calculating the flow volumes along the line of the Ebro using kinematic studies (based on gauging station data) and a regulated system is particularly important. The flows which the CAUMAX application provides always relate to the natural system for rivers, meaning that, in those cases where the watershed is regulated to a significant degree, flows have been taken from the data series logged by gauging stations to reflect how the contributing basin actually functions. At any rate, the values which CAUMAX provides for each river section always serve as a reference, especially in those cases where no alternative hydrological calculation procedure is used.

According to the scheduling in the Directive, the new FRMP for the Ebro Area is due to have been approved by December 2021 and within it the programme of measures will have been reviewed that also applies over the middle stretch of the Ebro. These are offered grouped into seven different topic areas that encompass:

1. **River and hydrological / forestry restoration,** which we will go on to examine and is covered in the types of intervention that are carried out along the mid-section of the Ebro.

2. The **draining of linear infrastructure,** with examples that we will also cite as illustration.

3. **Flood forecast.** This is a commitment to improving our ability to forecast, which in the Ebro basin is represented by the Decision Assistance System, the SADEbro. This allows improved management of flooding with optimised intervention of the basin's regulation infrastructure.

4. The **civil protection measures** used to safeguard people and property before, during and after a flood, which are fleshed out in the municipal, district, regional and national civil protection plans to guard against flood risk.

5. **Territorial planning and urban development.** This part addresses the need to make the uses to which the land is put in flood zones compatible with flooding as a phenomenon. The answer to this is should be found in the regulatory framework and planning by government bodies.

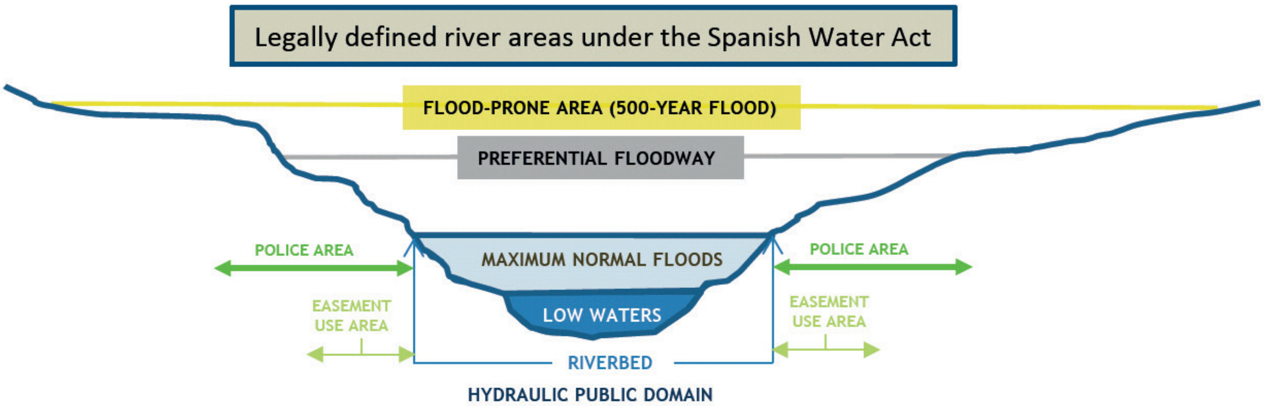
6. **Promoting insurance,** to curtail economic vulnerability to flooding and intended to involve private individuals, as well as those who own property and engage in business activities that are exposed to floods. Here, the Consorcio de Compensación de Seguros has an extremely important role to play in the recovery process.

7. **Structural measures.** Associated with a cost/benefit analysis and which represent the civil engineering solution wherever people and property have to be protected and which, in combination with improved forecasting in preparation for flood events, serves to offset their adverse effects.

This configuration of measures reflects arrangements based on shared responsibility among all the social stakeholders, government bodies (from the European Union down to local level), various different entities, associations, universities and individuals, etc.

The regulatory framework and self-protection

We have mentioned that territorial planning is one of the sets of measures that is included in the Flood Risk Management Plan. The latest amendment to the Hydraulic Public Domain Regulations of December 2016 identified the uses and activities that are vulnerable to flood risk.



The more specific nature of current regulations allows determination of adequate and proportional measures for uses in Preferential Floodway Areas (within the flood zone and associated with surges having a 100-year return period), which are allocated to reducing exposure and vulnerability to flood risk, as well as the avoidance of further set-ups of vulnerable activities in the Preferential Floodway Area.

Land-use limitations applicable at National level

Land Use	Preferential floodway: Rural land	Preferential floodway: Urbanized land	Preferential floodway: Special regime for municipalities with high likelihood of flood	Flood-prone area: Rural land	Flood-prone area: Urbanized land
School or health centres, retirement homes, disability care homes, sports centres, penitentiary facilities, fire stations, Civil Protection facilities	No	No	Only if there is no alternative location and if it is designed with security conditions	To be avoided, unless there is no alternative location and if it is designed with security conditions	Can be permitted if security conditions are considered to the possible extent
Large commercial areas where crowds of people could gather	No	No	No		
Buildings, repair works, rehabilitation or change of use, underground garages, basements and surface car parks, and other underground constructions	No	Yes, with security conditions	Yes, with security conditions	Yes, with security conditions	Yes, if security conditions are considered to the possible extent
Facilities where products likely to be hazardous to human health and the environment are handled such as gas stations, industrial treatment plants, waste stores or electrical facilities for high and medium tension	No	No	No	Yes, with security conditions	Can be permitted if security conditions are considered to the possible extent
Campsites, accommodations areas and buildings associated with campsites	No	These activities do not usually occur in urbanized land. If they happen to exist, at least the corresponding security conditions must be guaranteed	Yes, with security conditions and outside the police area	To be avoided, unless there is no alternative location and if it is designed with security conditions	
Urban waste water treatment plants	Only if there is no alternative location or if systems are compatible with floods		Only if there is no alternative location or if systems are compatible with floods		
Greenhouses, non-permeable enclosures and fences, material or waste storage	No		No	Yes	Yes
Changes in land morphology that could alter the capacity of discharge	No		Yes	Yes	Yes
Livestock breeding farms	No		Yes, with security conditions and outside the police area	Yes	Yes
Linear infrastructures in parallel to the riverbed	Only if there is no feasible alternative to these infrastructures and if the latter have been designed minimising risk		Only if there is no feasible alternative to these infrastructures and if the latter have been designed minimising risk	Yes	Yes
Sanitation and water supply infrastructures and other underground pipes; works for maintenance, enhance and protection of existing infrastructures	Yes	Yes	Yes	Yes	Yes
Buildings for agricultural use with a maximum of 40 m^2 and works associated with water uses allowed by Spanish Water Act	Yes, with security conditions	Yes, with security conditions	Yes, with security conditions	Yes	Yes

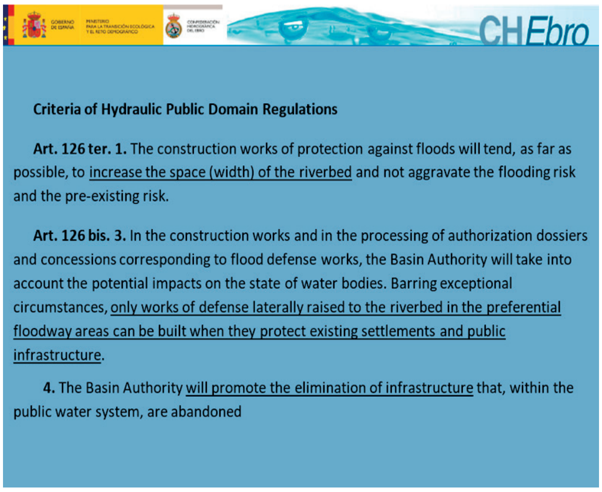
NIPO: 013-17-041-1 - D.L. (inglés): M-7690-2017

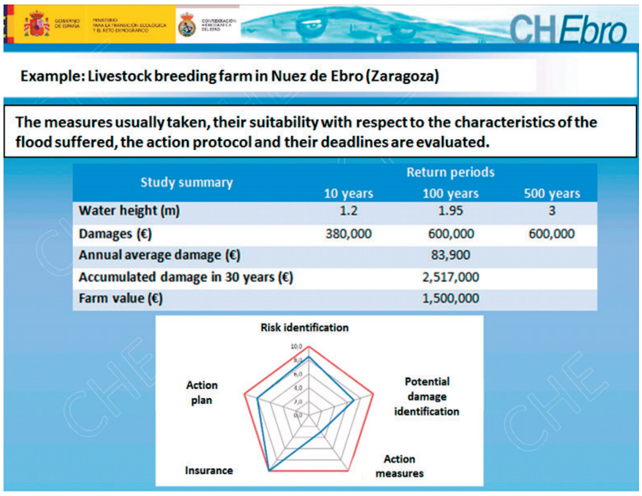
The latest amendment of the Hydraulic Public Domain Regulations (RDPH for the Spanish “Reglamento del Dominio Público Hidráulico”) of December 2016 proposes that, to the extent that it is possible, the tendency should be to “widen the breadth of the channel and not aggravate floodability and the pre-existing risk”. It also suggests only building defensive construction work raised above the sides of the watercourse in the Preferential Floodway Area “when these protect existing population centres and public infrastructure”.

Yet, these measures are not merely directed at laying down how we should approach our relationship with the flood zone from now onwards, as efforts have also been made to mould life as it already is to flood risk by taking protective or adaptive action to reduce the vulnerability of pre-existing elements, or else by removing them if we cannot manage to do this.

In this respect, the Ministry for the Ecological Transition and the Demographic Challenge has published a series of guides including some on reducing the vulnerability of buildings to flood risk, adapting farming and livestock concerns to the risk, recommendations about refitting buildings in flood zones and one on good practices in action to preserve, maintain and improve watercourses.

Following these criteria and within the scope of the Ebro Resilience Strategy, the Ebro Basin Authority (CHE for the Spanish) is conducting a pioneering campaign in Spain featuring a hundred specific studies of adaptation work on farms and/or livestock concerns at no cost to those wishing to benefit from it. The studies are being carried out among volunteer owners and they conclude with a presentation of alternative solutions plus a cost/benefit analysis for each of them.





On top of this, there are plans for ordinary management of the CHE which also boost resilience to flooding.

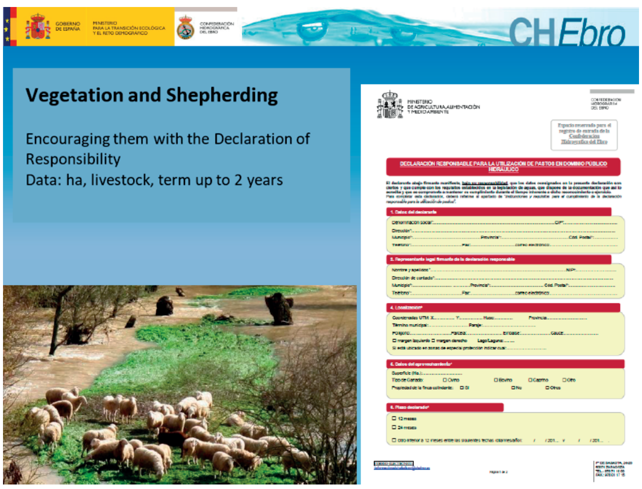
Within the context of the Ebro Area's Hydrological Plan, in 2016 a standard **Declaration of Responsibility was defined for processing minor activities to preserve the Hydraulic Public Domain (HPD).**

The declaration means speeding up and cutting down on processing for interventions of little consequence which third parties apply for who have to have authorisation from the basin authority when the actions satisfy two preconditions:

1. They are outside protected areas (subject to specific environmental rules).
2. They do not affect other parties.

To be precise, the **following are held to be minor maintenance activities:**

- Removing dead trees and pruning those that hamper access to the watercourse or its right of way, provided that these do not involve any loss of the bank's arboreal substrate.
- Removing dead trees and pruning those that diminish the watercourse's drainage capacity.
- Removing items carried along by the current and which block the watercourse, especially crossings or work that represents an element that degrades or pollutes the Hydraulic Public Domain.
- Maintenance on gauging sections in official networks of gauging stations.



The CHE has recently passed another measure that is intended to foment a commitment to flood-resistant crops in the Ebro basin.

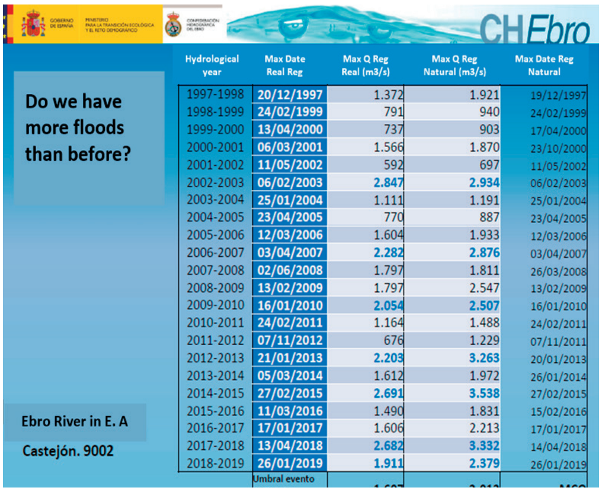
This has been brought in by regularisation of the charges on occupying public land with farming. This has changed from an across-the-board levy to one which takes into account two factors: the zoning according to the flood period and the rateable value of the adjacent property adapted to the Ebro basin.

There is moreover a discount on the charge for agricultural crops where there is HPD occupation and the intention is to replace them with forest crops that are compatible with flood risk. The charging of fees for occupation and farming activity is established in Heading VI of the recast text of the Waters Act and implemented in the Hydraulic Public Domain Regulations which set out the formal procedures for concession and authorisation in using the HPD.

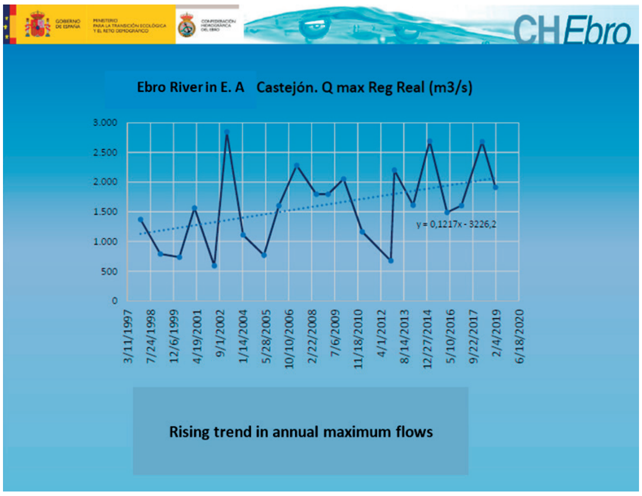
A better understanding of the mid-section of the Ebro

Increasing our knowledge is one of the keys to managing the future and one of our lines of work. Technology tools allow us to obtain data that provides an increasingly accurate reflection of the real situation and therefore to take decisions about taking on measures in the most affected areas.

The kinematic data logged speaks to us of a rising trend in annual maximum flows and a higher recurrence of extreme phenomena over recent years (comparison is made between the actual system of flows, lamination on account of reservoir management and the natural system, which means the maximum flows that might have occurred without dams):



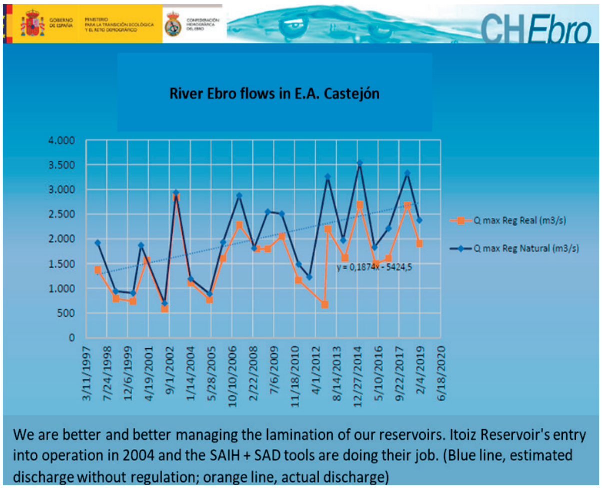
Hydrological year	Max Date Real Reg	Max Q Reg Real (m3/s)	Max Q Reg Natural (m3/s)	Max Date Reg Natural
1997-1998	20/12/1997	1.372	1.921	19/12/1997
1998-1999	24/02/1999	791	940	24/02/1999
1999-2000	13/04/2000	737	903	17/04/2000
2000-2001	06/03/2001	1.566	1.870	23/10/2000
2001-2002	11/05/2002	592	697	11/05/2002
2002-2003	06/02/2003	2.847	2.934	06/02/2003
2003-2004	25/01/2004	1.111	1.191	25/01/2004
2004-2005	23/04/2005	770	887	23/04/2005
2005-2006	12/03/2006	1.604	1.933	12/03/2006
2006-2007	03/04/2007	2.282	2.876	03/04/2007
2007-2008	02/06/2008	1.797	1.811	26/03/2008
2008-2009	13/02/2009	1.797	2.547	13/02/2009
2009-2010	16/01/2010	2.054	2.507	16/01/2010
2010-2011	24/02/2011	1.164	1.488	24/02/2011
2011-2012	07/11/2012	676	1.229	07/11/2011
2012-2013	21/01/2013	2.203	3.263	20/01/2013
2013-2014	05/03/2014	1.612	1.972	26/01/2014
2014-2015	27/02/2015	2.691	3.538	27/02/2015
2015-2016	11/03/2016	1.490	1.831	15/02/2016
2016-2017	17/01/2017	1.606	2.213	17/01/2017
2017-2018	13/04/2018	2.682	3.332	14/04/2018
2018-2019	26/01/2019	1.911	2.379	26/01/2019
	Umbral evento	[illegible]	[illegible]	[illegible]

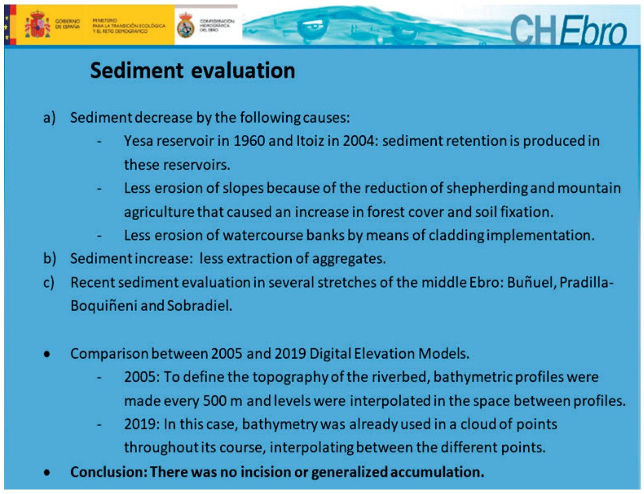


The development of forecasting tools has enabled optimisation of regulation infrastructure management in flood events, which could lead us to the false notion that the full weight of damage limitation should fall on such management, which is not possible: firstly because there are not dams on all water courses, and secondly because, as has been shown, they cannot avoid just any event, especially in high return periods (major river floods).

Knowledge is also helping us to debunk another of the myths about the actual situation regarding the Ebro waterway and which was leading us astray in efforts to hit on the necessary definition of the right measures. This concerns the widespread belief that there has been a build-up of sediment, which translates into the public calling for a "clean-up". This would in actual fact imply wholesale dredging activity as the core solution.

In 2019, new bathymetry of the watercourse was conducted along the middle stretch of the Ebro (the previous exercise having been in 2005), which allows us to conclude that no incision nor generalised accumulation has occurred with respect to the riverbed.





Types of action to improve safety in flooding

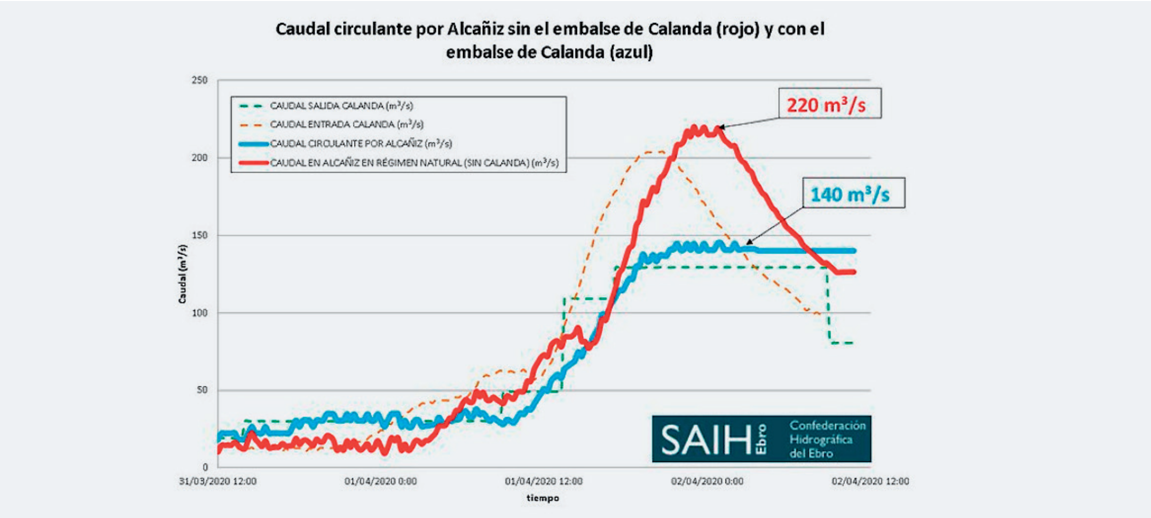
It is calculated that, over 2003-2018, the investment made in water-channel action and emergencies in the Ebro basin amounted to more than 151.5 million euros, which works out at an annual average of 9.5 million. The turnaround in interventions and the lines marked out by planning are intended to ensure that what is invested now reduces the fallout and damage, and therefore the economic impact of each bout of flooding.

All the issues which we have thus far discussed are now being implemented in the Ebro basin, particularly along its mid-section. Being able to draw on an increasingly sound knowledge thanks to the studies referred to, having experienced several extraordinary events within only a short space of time, together with both the administrative and technical involvement of this organisation, have allowed us to advocate actions that satisfy the criteria set out for curbing flood risk at EU level, first in the form of pilot proposed solutions and then generally.

In executing the emergency action following the extraordinary flood events in 2015, and particularly in 2018, the Ebro Basin Authority began to implement a programme of measures aimed at, not only recovery, but also building up resilience via action that also kept to the lines in the EU Floods Directive and consequently the Flood Risk Management Plan. These interventions are chiefly intended to protect population centres.

We have grouped these actions into **five categories** and they have both proved effective and show us the path to follow which, as we have already outlined, involves establishing varied blends of measures. All of this is within a regulatory framework that is increasingly illuminating as regards action on the watercourse and while bringing in interventions away from the waterway that enhance self-protection.

We now move on to examination of these categories. In addition to direct interventions, we have one sort known as **Type T0,** which also falls within the direct remit of this organisation and consists of **managing regulation infrastructure** and reservoirs thanks to the development of forecasting systems such as our Decision Assistance System (SADEbro) and our telematic control networks, the internationally recognised Automatic Hydrological Information System (SAIHEbro), which, where possible, allow moving flows to be reduced and surge points on certain tributaries not to run into each other.



Beneficial and reducing effect (lamination) for the municipality of Alcañiz from managing the Calanda reservoir (Teruel) during a flood event in April 2020. The blue line is the actual circulating flow whereas the red one is the hypothetical one, should not have the flood being laminated by the Calanda reservoir.

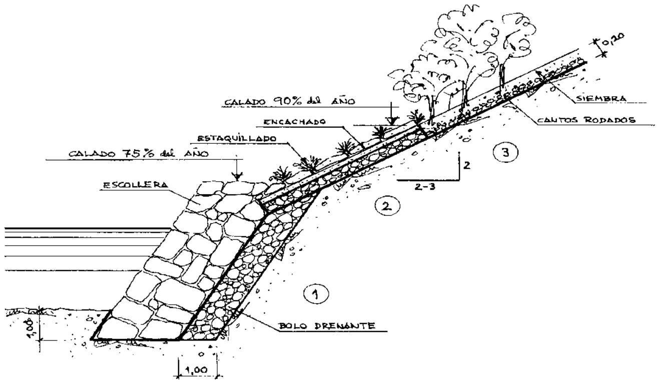
Type T1: improving structural defences

Action aimed at repairing "motas" (longitudinal earthen dykes) that channel the mid-section of the course of the Ebro, especially the dykes or walls that protect urban population centres, using reinforcement and structural solutions that improve their shielding ability.

The various different flood events subject these structures to progressive wearing over time. Furthermore, during extraordinary events featuring major river surges faults and breakage are caused which have to be repaired. In such cases, the repairs use selected materials which, together with careful management of how they are performed, achieve the goal of improving the structure to face future events of a similar nature, thus providing a sounder defence (more waterproof and resistant) which heightens safety. Both for earthworks and concrete structures, repairs of raised defences can be extended to their foundations in certain cases. With slopes, if necessary they are reinforced at the base and replanting is carried out up to the top.

- **Construction of new infrastructure**
  In 2nd line> of 7 km
- **Modification of existing infrastructure: repair, levelling or reinforcement**
  >150 km in 2015
  >110 km in 2018

Repair and refurbishment of a dyke in Osera de Ebro (Zaragoza).



Section type. Characteristic depths.

Type T2: improving the draining capacity of the watercourse

This involves efforts to restore the hydraulic part of the drainage system.

In some cases action is taken within the channelled area between dykes as a result of an over-accumulation in certain zones of sediment (this is removed or redistributed) or vegetation (this is cut back and removed).

Here, "curage" techniques are used and intervention takes place on large isles, eyots and thickets, by opening up offshoots among the vegetation and then carving out their beds to encourage the sediment to be shifted by normal flows.

Using "curage" to make large masses of sediment densely populated with vegetation (isles and eyots) passable is yielding visibly good results in the Ebro basin. The offshoots have to be plotted out by taking advantage of old water distributaries that have ceased to be of hydraulic use over time and restoring their connection to the main watercourse. Similarly the width of these newly opened-up offshoots should be properly scaled so as to achieve a speed of water throughput that makes sedimentation unlikely and works in favour of self-maintenance of their useful section. Efforts begin by opening up pathways through the vegetation then comes the dredging (deep furrowing) of the bed of the offshoot, which enables the breaking up of the crust and deep stirring of sediment, which requires less energy for ordinary rises in the water-level to move.

Work has currently taken place in several areas which together cover over 80 hectares. These remain ongoing.

In several other cases, more space is given to the river (i.e. width) by removing, setting back or lowering dykes. Setting dykes back restores space for the water channel on stretches where gaining breadth has proved very positive in encouraging expansion of the river and offsetting the erosional effects of the current as the flow running through it loses speed.

T2-1 Vegetation treatments and removal of obstructive elements
> 10 ha

T2-2. Lowering/setting back/ removing of dykes
Actions in more than 14 km:
- Setting back >11,000 m
- Lowering >2,000 m
- Removing >1,600 m

A. Setting back a dyke in Alfaro (LR) 710 m. River Ebro.
B. Dyke removal at Cabañas de Ebro (Z).
C. Novillas (Zaragoza). Work on vegetation and obstructive elements. River Ebro.

T2-3. Permeabilization of large masses of vegetated sediments by opening up offshoots of free circulation applying the "CURAGE" technique

27 Actions carried out:

- Alfaro
- San Adrián (2)
- Calahorra (2)
- Buñuel
- Viana
- Novillas (3)
- Boquiñeni
- Alagón (2)
- Torres de Berrellén
- Sobradiel (3)
- Utebo (2)
- Monzalbarba
- Alfocea (2)
- Alcala de Ebro
- Villafranca de Ebro (2)
- Pina de Ebro (2)

>19 ha in Natura Network

> 64 ha out of Natura Network

"Curage" in Utebo (Zaragoza). Above: plan. Bottom: during flooding of the Ebro.

River Ebro, “Mejana del Tormo” in Alagón (Zaragoza).

Curage in Alfaro (La Rioja) after the action of a flood on the River Ebro.

Type T3: permeabilization involving infrastructure. Relief channels

Permeabilization means taking action to improve the passability of flows (by increasing the drainage section) as they move under infrastructure crossing the watercourse (bridges). Action is also taken with respect to infrastructure away from the channelled watercourse (embankments of roads, railways or other civil engineering work) that holds in water and creates large dammed areas when the waterway has overflowed onto the floodplain.

Permeabilization can be permanent or temporary (integrable frames). The former kind is performed on bridges within the watercourse. The second sort is normally used away from it and allows a certain degree of control over the bursting of riverbanks.

Relief channels are new distributaries additional to the main course and dug out with a bottom level higher than the latter. They allow the river to divert a substantial part of the flows in circulation along them when there are high water levels (i.e. in floods). Sometimes they are dug in the area between dykes and at others alongside.

Besides bringing down the surface level in the section next to the main watercourse, which improves its safety in any overflow (vital in stretches besides population centres), this benefits how defensive structures perform by sapping the energy striking against them and consequently works in favour of a lower risk of structural breakage, both from erosion of the materials of which they are built and from hydraulic thrust.

T3-1. Infrastructure permeabilization
4 Permeabilizations:

- Novillas
- Frías
- Pradilla de Ebro
- Pina de Ebro

Pradilla de Ebro, increasing the permeability of the bridge over the river Ebro.


Frames on the river Ebro next to the CV-04 bridge in Novillas (Zaragoza) and integrable frames on the A-1107 road. Pina de Ebro (Zaragoza).

T3-2. Construction of relief channels
6 Relief channels:
- Alfaro
- Novillas
- Alcalá de Ebro
- Cabañas de Ebro
- Pina de Ebro
- Tauste

River Ebro relief channel at Alcalá de Ebro (Zaragoza).

Type T4: Overflow safety cordon

These are actions to defend population centres in situations where the river (upstream or downstream) flows outside the channelled course as a result of either breaking or flowing over the defensive structure (dyke).

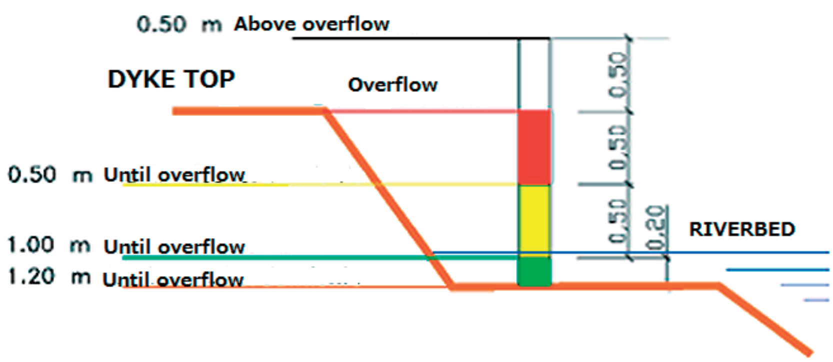
Existing infrastructure is used (paths, roads, walls...) which is levelled or built up to construct a cordon that surrounds the town or city centre to either delay or avoid it being flooded by water that has burst its banks. Sealing elements have to be applied to structures along the perimeter (livestock crossings, irrigation ditches...) that prevent or hinder water from coming into the urban centre.

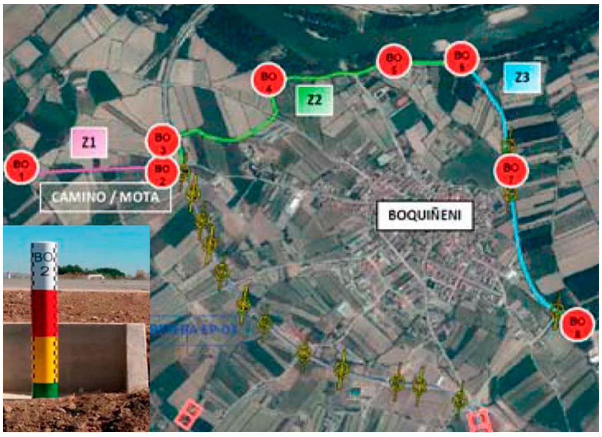
Boundary posts are also installed along the cordon, which are intended to enable monitoring of the progress of water-levels in situ and at any given time to find Height/time correlations to assist in decision-making, such as in the event of any evacuation.

To date, these have been formed at 12 urban centres along the Ebro and they continue to be made.

12 Urban centers:

- Novillas
- Sobradiel
- Alcalá de Ebro
- Alfocea (Z)
- Pradilla de Ebro
- Boquiñeni
- Cabañas de Ebro
- Pina de Ebro
- Torres de Berrellen
- Remolinos
- Monzalbarba (Z)
- Quinto





Lay-out of the safety cordon at Boquiñeni (Z). River Ebro.

Setting up caissons at the confluence of the rivers Queiles and Ebro. Tudela (NA).

Type T5: Temporary flood areas

These are mainly farming areas away from the zone between dykes and adjacent to the watercourse, which enable part of the flow along the channel to be diverted and temporarily stored safely and without significant damage in the event of a river surge. They can be controlled (using a floodgate) which allows action to be taken by opening or closing it, or free (without a floodgate). All of those currently being created are free.

By drawing away significant volumes of water from the river and diverting them laterally, the presence of a temporary flood-prone area does not just bring benefits along the stretch of river located downstream (as one might think at first). The fields that become flooded within the area also reap benefits in several respects.

Thus, if a dyke bursts or there is overflowing (even from upstream along the bank), the impact on the fields and their infrastructure turns out to be greatly diminished or even non-existent, as the dammed water acts with a cushioning effect. The damage to the dyke itself is reduced, since the drop is reduced from it having been overrun. There is also a reduction in the differential between the hydrostatic pressures on the inner and outer slopes of the dyke. Finally the emptying out of the area occurs in a far shorter time as it is equipped with additional relief devices that allow the pent up water back into the waterway at the time when the river level falls below that of the flooded area.

At the moment, the 11 areas constructed (all in Aragon) allow temporary diversion and storage of over 11 hm3, taking up slightly more than 80 ha. It should be pointed out that a higher number of areas benefit proportionally, given that we would be letting the river use “extra” areas at precisely the time when this is most needed and not before; in other words in flood events when the corridor between dykes is often not enough to cope.

11 Areas with> 11 hm^3 of storage:

- Novillas
- Pradilla
- Pina de Ebro (2)
- Alagón
- Boquiñeni
- Remolinos
- Torres de Berrellén
- Sobradiel
- Utebo
- Alfocea

A. Controlled flood-prone area in Novillas (Z). River Ebro.
B. Free temporary flood-prone area at Mejana de la Cruz in Alagón (Z). River Ebro.

Ebro Resilience

This experience of several different types of action has helped us define and draw up the Ebro Resilience strategy. The scope: a total of 324 km of waterway over the mid-section of the Ebro and lower stretches of tributaries from the mouth of the river Iregua in Logroño (La Rioja) to La Zaida (Zaragoza), which represents a catchment area that takes in 1,033,000 inhabitants.

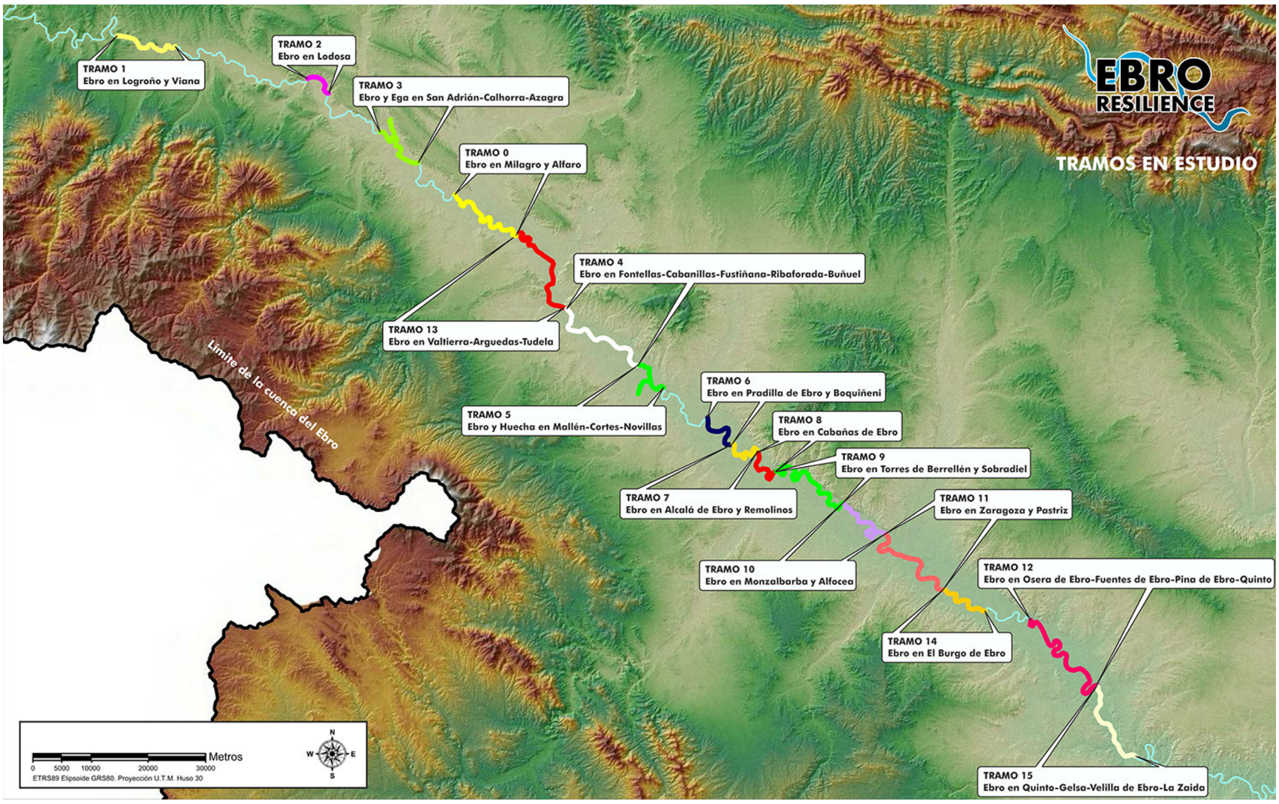
The strategy is a partnership mechanism for implementing flood risk management measures along the mid-section of the Ebro. It is the fruit of coordination among government bodies: The Ministry for the Ecological Transition and the Demographic Challenge, the Ebro Basin Authority and the regions of La Rioja, Navarre and Aragon, while also striving for collaboration with local councils and consensus with stakeholders in the territory.

Ebro Resilience divides its proposed river model into two separate zones: urban and non-urban environments.

The design for urban zones is to protect localities against river surges with a 25-year return period and for non-urban zones it is to ensure the draining away of the maximum normal water level rise and a reduction of effects for river surges for a return period of up to 10 years.

Within the Ebro Resilience Strategy detailed studies are being made of the flood risk on the 15 stretches with the biggest detected problems in surge events. The studies will define the actions to be taken to meet the objectives outlined in the previous paragraph. The sections being studied are:

1. The river Ebro in Logroño and Viana.
2. The river Ebro in Lodosa.
3. The rivers Ebro and Ega in San Adrián, Calahorra and Azagra.
4. The river Ebro from Alfaro to Tudela.
5. The river Ebro from Fontellas to Buñuel.
6. The rivers Ebro and Huecha in Mallén, Cortes and Novillas.
7. The river Ebro in Pradilla de Ebro and Boquiñeni.
8. The river Ebro in Alcalá de Ebro and Remolinos.
9. The river Ebro in Cabañas de Ebro.
10. The river Ebro in Torres de Berrellén and Sobradiel.
11. The river Ebro from Utebo to Zaragoza.
12. The river Ebro from Zaragoza to Pastriz.
13. The river Ebro in El Burgo de Ebro.
14. The river Ebro between Osera de Ebro and Quinto.
15. The river Ebro between Quinto and La Zaida.



And no less important is the informative, participative and inclusive campaign being carried out among those affected, social partners, users and, naturally, government bodies. Thus the actions to be analysed in the studies will incorporate suggestions provided during the participative sessions in the three regions concerned.

Together with these studies over the mid-section of the Ebro, the Ebro Basin Authority is currently undertaking two interventions to serve as benchmarks for river restoration that are intended to reduce the impact of flooding: the hydrological connection and the recovery of habitats on meanders in the lower section of the Arga in Funes, Navarre, and the morphological adaptation and environmental recuperation of the river Ebro at the Paraje de La Nava in Alfaro, La Rioja.

Hydrological connection on the lower section of the Arga in Funes (Navarre)

The project in Funes has become a pilot intervention for what the Ebro Resilience Strategy will mean on the mid-section of the Ebro. The starting point is to achieve coordination between all the administrations concerned to reduce the effects of flooding, though doing so via interventions that seek to restore the natural environment in the area where possible by reviving habitats.

> Restoring the natural environment at the confluence of the rivers Arga and Aragón is included within the Environmental Advancement Plan for Adaptation to Climate Change in Spain (PIMA-Adapta) and the FRMP for the Ebro basin (PGRIEbro).

The tasks included in the engineering work are aimed at moderating flood risk in the town of Funes. To this end, action is being taken to recover the river Arga flood plains, improve the drainage at the confluence of the rivers Arga and Aragón, enhance the quality of waters and restore riparian habitats characteristic of the zone's natural protected areas.

The funding for the project is being met by the Directorate General for Water at the Ministry for the Ecological Transition and the Demographic Challenge, while the Navarre regional government is covering compensation for loss of profits on poplar tree cultivation and the Funes council has made communal land available for the work.

Intervention on the River Ebro at the Paraje de La Nava (La Rioja).

The tasks of morphological adaptation and environmental restoration on the river Ebro as it passes through the Paraje de La Nava in Alfaro (La Rioja) are the first large-scale project in implementing the Ebro Resilience Strategy on the mid-section.

The intervention began in December 2019. The work mainly consists of removing 1,806 metres of the existing defences which runs parallel to the watercourse to be rebuilt in a position where it has been set back at a distance of between 100 and 300 metres along some 1,376 metres.

These tasks will be undertaken during the summer of 2020 in the low-water period. With the setting back of the defensive system some 30 hectares of irrigated plain will be reclaimed, where river restoration will take place featuring the planting of indigenous fertile plain species (7,000 assorted poplars, 1,600 ash trees and 1,800 bushes and shrubs such as willow, tamarisk, dogwood, hawthorn, blackberry and rose-bushes). There are also plans to create a zone of habitats suitable for the European mink by building a mosaic of wetland environments in the reclaimed plain area with over 1,300 aquatic plants.

Conclusion

The upkeep of public waterways is the competency of the Water Commissioners of the Basin Authorities (R.D. 984/1989 of 28 July) and it is important to appreciate what this means. Public waterways are the land covered by waters at the maximum level of normal rise, which, on the Ebro's mid-section, is that which takes place every two or three years. It is therefore the duty of the basin authorities to protect the banks and adjacent plains and to ensure that the watercourse is able to evacuate a normal river flood, but not those classed as extraordinary, which, by definition, run along the river banks(i.e. across the flood-prone zone, its flood plain).

This is reasonable, given that ordinary flooding runs along the hydraulic public domain but extraordinary floods affect privately-owned land located in the bordering areas or policed zones where the basin authorities do not have full competency.

The role of preserving waterways that is commended to basin authorities has a restriction on it that is set out in Law 10/2001 of the National Hydrological Plan (article 28.4), which stipulates that actions involving public waterways located in urban settings shall be the responsibility of the competent authorities regarding territorial planning and urban development (regions and, mainly, councils).

Nonetheless, the mid-section of the Ebro presents a high risk of flooding, with extraordinary floods that cause substantial damage and endanger the lives of the inhabitants on the plain, the frequency of floods having increased in recent decades.

From the flood in 2003 onwards, the Ebro Basin Authority began to implement original measures aimed at achieving integrated flood management. On one hand, actions started to be undertaken that were designed to reclaim river space. On the other hand, also beginning in that year, the Decision Assistance System started in operation, which incorporates a set of hydro-meteorological forecasting models and enables improved management of reservoir control in flooding situations. In addition to this, the reservoir at Itoiz (Navarre) was commissioned in 2004, which has considerable capacity for laminating flooding on the mid-section of the Ebro.

The coming into effect of the 2007 Floods Directive represented a change of model, when the basin organisation drafted the first **Ebro Flood Risk Management Plan (December 2015),** which is the framework instrument that covers a whole range of measures for the government bodies to implement which have competency for several issues, such as urban development, territorial planning, the natural environment, forest management, insurance, hydrology, hydraulics, etc.

In 2010, **Royal Decree 903 on assessing and managing flood risks** was published, which transposes the earlier directive and establishes that the Ministry for the Ecological Transition and the Demographic Challenge, the Ministry of the Interior, the regional and local governments shall, within the scope of their respective competencies, draw up the programmes of measures and perform the actions to manage flood risk. This means that managing the risk of flooding (extraordinary river floods) is the responsibility of all the arms of government involved.

Extraordinary river floods are inevitable, but we can make them less frequent, relieve the harm they cause and improve the recovery of people and property that are affected. Experience has taught us that we cannot resolve the problem by clearing and cleaning up rivers.

With these goals in mind the Ebro Resilience Strategy was came into being in 2017, which is framed within the National River Restoration Strategy. A new management model for the river Ebro with the philosophy of reclaiming river space, giving it more room to laminate (to begin to store water at its edges and slacken its flow as it moves forward) and for the water to both slow down and drop in depth, such that this reduces damage.

This strategy embraces both non-structural measures: development-related, adaptation of vulnerable (urban, agricultural and livestock) elements, restoration and safeguarding of ecosystems, and acquiring land; and structural measures: setting back dykes, controlled flood areas, permeabilization of infrastructure, occasional dredging, relief distributaries, "curage", etc.

The scope of this project is a 324 km length of the river Ebro at its middle section, from Logroño to La Zaida, with over a million affected inhabitants on the land neighbouring the river.

It is a strategy which is being implemented by the regional governments of La Rioja, Navarre and Aragon in conjunction with the Ministry for the Ecological Transition and the Demographic Challenge, as well as the Ebro Basin Authority. It is also one which could not be successfully brought to fruition without the determined and vital participation of councils, affected parties, those performing irrigation, environmental groups and universities.

Pilot cases for adapting to flood risk

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1. Introduction

Today's ecological challenges call for collective and individual changes on different scales which both factor in uncertainty as a resource to work with and aspire to more resilient societies.

In recent years, and driven by serious episodes such as the river flooding in Europe or hurricanes Sandy and Katrina in the United States, cities the world over are working on ambitious comprehensive strategies that fuse together global thinking on resilience with specific local conditions. With multidisciplinary teams joining forces that comprise architects, engineers, landscapers and town planners, along with contributions from the fields of natural and social sciences and the involvement of new stakeholders, this systemic approach concedes that we are vulnerable to future disasters and proactively designs responses from the standpoint of the landscape, cities and ultimately buildings.

Figure 1. Flooding in Los Alcázares (Murcia) in September 2019.
Source: Segura River Basin Authority.

In Spain, flooding represents the natural risk that causes the most significant harm in terms of both property and human life. In light of this, adapting buildings can make a substantial contribution to keeping economic loss down and boosting the safety of those inside.

Having publicised its *Guides to adapting to flood risk,* the Directorate General for Water at the Ministry for the Ecological Transition and the Demographic Challenge is working on a set of *pilot cases for adapting to flood risk.* These seek to put the concepts in the guides into practice, pick out the general lines of action to apply to buildings according to their purpose, location and constructional attributes, and draw together good practices.

They therefore advance solutions within a multi-scale approach to resilience: long-term territorial transformations which are supplemented by immediate and timely measures at a local level that can withstand events for which no response capability exists in current circumstances.

2. Background

Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks aims to set up a framework to focus on "the reduction of potential adverse consequences of flooding for human health, the environment, cultural heritage and economic activity". Other EU directives associated with river management, such as the Water Framework Directive and the Habitats Directive, present a broad complementary setting for integrated flood risk management.

In Spain, Royal Decree 903/2010 of 9 July on the assessment and management of flood risks marks the transposition of the Floods Directive to the state legal system. On the other hand, Royal Decree 638/2016 of 9 December amending the Hydraulic Public Domain Regulations and the Hydrological Planning Regulations (among others), identifies those activities that are vulnerable to river surges and imposes certain basic limitations on using flood zones.

The National Flood Zone Mapping System (SNCZI for the Spanish) is a support tool for river area management, risk prevention, territorial planning and administrative transparency. At its core is the flood zone map viewer, which allows the public to access information on floodability.

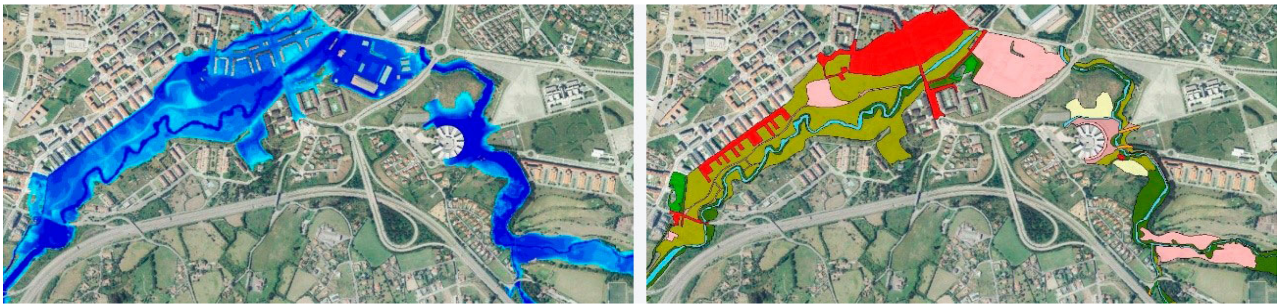


Figure 2. Area around the Gijón Polytechnic School of Engineering (Asturias): hazard map and map of risk to business activities T=500.
Source: SNCZI.

Flood Risk Management Plans (FRMPs) are the reference documents for the government and society in general as regards managing river overflows. Their key content is the programme of measures (including those that concern territorial and urban planning), which includes producing technical guides to reduce the vulnerability of exposed elements.

The *Guide to reducing building vulnerability to flooding*, which has been drafted within a partnership agreement entered into between the Directorate General for Water and the Consorcio de Compensación de Seguros, provides information on risk management, building design, and both public safety and self protection measures to keep the loss which floods cause to a minimum.

Additionally, under the Environmental Advancement Plan for Climate Change Adaptation in Spain (the *PIMA Adapta plan*), the Directorate General for Water and TRAGSATEC have produced the following guides, which are being applied to several representative pilot cases:

Figure 3. Guides to flood risk adaptation.

- *Assessment of the resilience of urban population centres to flood risk: networks, urban systems and other infrastructure,* to help pinpoint the direct or indirect harm which a flood can cause to a city or its surrounding area so that action can be taken to enhance resilience.

- *Sustainable urban drainage systems,* to delve more deeply into the causes and consequences of urban flooding and achieve better rainwater management by using SUDSs.

- *Recommendations for constructing and fitting out buildings in flood zones,* to explain construction standards that apply to new buildings in flood zones and options for improving those already erected.

- *Adapting to flood risk on agricultural concerns and livestock farms,* to publicise the consequences of flooding and encourage risk reduction in agricultural and livestock environments.

3. Resilience to flood risk and multi-scale approach

The concept of resilience describes the ability of society or ecosystems to adapt to the risks they can withstand.

In the context of a climate emergency, Agenda 2030 represents an effective roadmap to tackle resilience with a wide-ranging approach that helps to safeguard the environment, health and public safety. Adopted in 2015 by the heads of state and government of the member countries of the United Nations, it proposes 17 Sustainable Development Goals (SDGs) that can be framed via integrated flood risk management.

Figure 4. Sustainable Development Goals 6, 11, 13 and 15.
Source: The United Nations Organisation.

The Spanish Urban Agenda, which was discussed by the Council of Ministers of 22 February 2019, offers a Decalogue of Strategic Goals where resilience and its ability to engender new benefits play a key role. Aimed at boosting participation and shared responsibility, it also espouses implementing risk governance that extends inclusion to all stakeholders (experts, governments, the private sector, civil society, etc.) in debate and management itself.

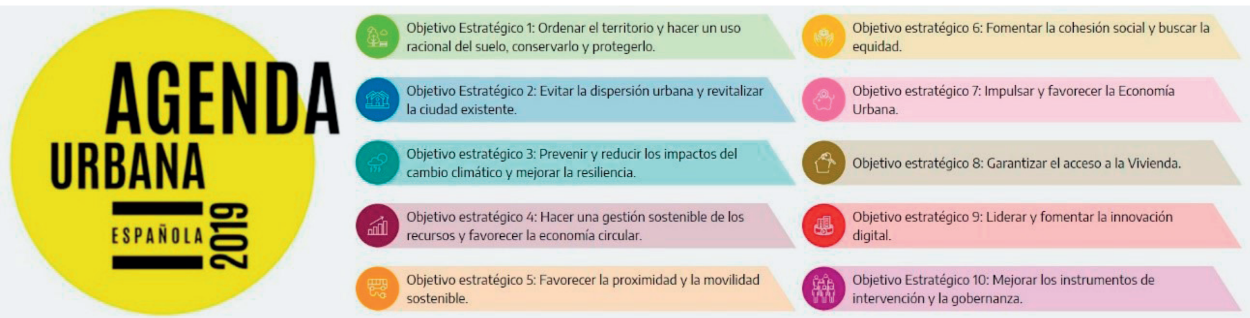


Figure 5. The Decalogue of Strategic Goals in the Spanish Urban Agenda 2019.
Source: Ministry of Transport, Mobility and Urban Agenda.

The strategies in flood and environmental sustainability management enable risk reduction while retaining or increasing the benefits which rivers provide, although in the case of legacy situations such as established population centres or strategic infrastructure in vulnerable zones they have to be backed up by protection mechanisms (Ollero, 2014). This multi-scale resilience approach proposes interaction between the ecological and the social systems built upon jointly protecting ecosystems and human activities to keep both functional and moreover produce extra assets. In this context, boosting resilience means planning slow processes on a global scale and being ready for sudden disruptions at local level (García García, 2016).

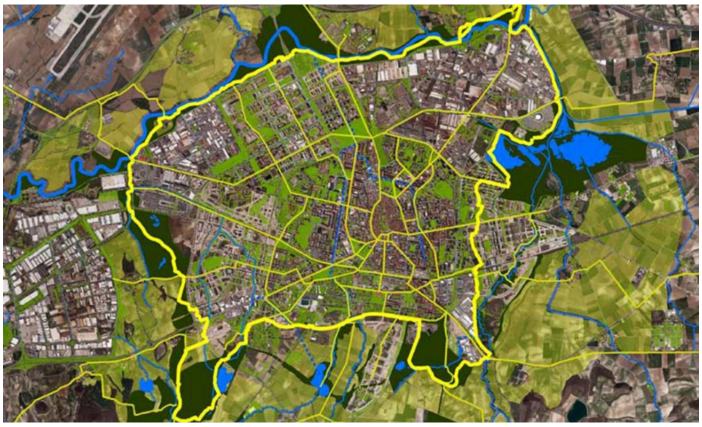


Figure 6. Green urban infrastructure in Vitoria-Gasteiz. Source: Centre for Environmental Studies, Vitoria-Gasteiz Council.

On an urban scale, besides having regulations and tools available to manage risk in a coordinated way, cities and communities must also progress towards new approaches and ideas that enable them to enhance their resilience and face up to future climate-related circumstances by blending adaptation with mitigation.

Within this context, green and blue infrastructure represents multifunctional solutions based on nature that are useful for flood risk management and yield environmental, economic and social benefits. This perspective governs the hydrological planning and management that Vitoria-Gasteiz (named European Green Capital 2012) is pursuing to address its flooding and drainage/sanitation problems (Marañón, 2019).

Sustainable urban drainage systems (SUDSs) are a preventive measure in managing rainwater that helps to minimise the impact of flooding. The strategy they use hinges on two key aims: keeping down the amount of water that reaches the end-point of the evacuation process and improving the quality of the water that is dumped into the natural environment. Municipalities such as Benaguasil (Valencia), which received the national Sustainable City Award in the water management category in 2015, show us that there are means and techniques to provide a fresh approach to treating rainwater by blending run-off management in with the urban landscape (Perales-Momparler and Valls-Benavides, 2013).

Figure 7. Cité Fluviale de Matra (Romorantin-Lanthenay, France). Source: CEPRI / Éric Daniel-Lacombe.

On an architectural level, floods cannot be avoided; yet their effects can be significantly diminished. Here, local government and individual initiative can play a decisive role in prevention by fostering exposure reduction, resilient building standards and self-protection measures.

With new building in risk zones, it is important to weigh up the options for implementing offsetting measures and accommodating uses that are compatible with flooding. Incorporating hydraulic transparency standards (buildings aligned with the flow of the current, building on piles, topographical alterations, public areas that slow down and drain water, etc.) allows water to flow past freely without holding up its natural movement. The design of the neighbourhood of Matra in Romorantin-Lanthenay (France) pre-empts any presence of water, which helps to improve how the risk is perceived instead of masking it (CEPRI, the European Centre for the Prevention of Flood Risk, 2014).

Several adaptive measures of a palliative nature already exist for buildings that have already been put up in risk zones and they are oriented towards lessening vulnerability to floods. The most notable are those which focus on avoiding contact between water and the building, preventing it from entering and minimising damage once inside (FEMA, 2014).

4. Pilot cases for adapting to flood risk: methodology

The pilot cases for adapting to flood risk propose broad courses of action and apply the content of the guides drafted to specific examples, while also drawing together good practices that have already been implemented, to facilitate their dissemination. In coordination with the various different hydrographic areas, highly diverse intended uses for them have been chosen (sanitary, institutional, teaching, industrial and cultural heritage purposes) in different geographical contexts. The methodology employed spans four phases:

Figure 8. Pilot cases for adapting to flood risk.

1. Risk characterisation: through collating mapping information available via the SNCZI and data on previous episodes of flooding. The buildings, the surroundings or locality under review and their context are analysed and a visit is made and the managers and users concerned are interviewed.

2. Exposure diagnosis: the source and main entry-points of water are identified, as is the potential damage that a flood would cause in the existing situation.

3. Adaptation proposal: several general self-protection measures for protecting people and the building and its equipment are set out, as well as actions that are recommended if flooding is expected in the zone and there is time to respond.

   Four types of action to mitigate damage affecting the building are distinguished: PREVENTING the water from reaching the building; RESISTING the entry of water into the building after it has arrived outside it; WITHSTANDING incoming water while taking steps to minimise damage, and ABANDONING use of the building when the risk is too high.

   The most usual step is to deploy temporary barriers. For them to be effective, they will have to meet a set of requirements: a height above the highest level of flooding envisaged,

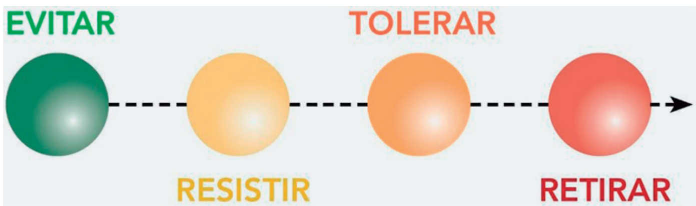


Figure 9. Measures intended to offset damage in the building.
Source: Guide to reducing the vulnerability of buildings to flooding. Directorate General for Water and the Consorcio de Compensación de Seguros.

water-tightness, resistance to both water pressure and the impact of water-borne objects, and availability, of both time and enough resources to move them into place. Other typical measures are non-return systems to head off flow-backs of sewage or bail-out pumps to evacuate build-ups of water and cut the time flooding is present and ensuring the continuity of available electricity in the event of black-outs by using uninterrupted power supply (UPS) units.

Then there are three different types of action to mitigate damage to equipment: RISING (lifting the exposed item over the flood level), RELOCATING (moving it to a non-exposed area) and PROTECTING (keeping it where it is and taking the necessary steps to limit damage).

4. Economic appraisal: A cost/benefit analysis is performed to convey how appropriate it would be to invest in prevention using the methodology outlined in the *Guide to reducing the vulnerability of buildings to flooding.*

The calculation is made by taking into account building and equipment damage, as well as the loss from business stoppage. Losses are worked out according to the percentage affected for 0.5, 1.5 and 3 metres of flood depth. Based on this information and using a proportion parameter, several risk hypotheses are considered subject to return periods of 10, 100 and 500 years and the different depths involved. By applying a mathematical model that incorporates loss levels and frequencies we can obtain the average annual loss and then multiply it to arrive at the potential cumulative loss over 30 years. Using these determinants, separate preventive strategies are proposed along with their estimated cost of implementation. Lastly the residual loss or estimated value of the loss after taking the set of preventive steps is calculated and the reduction in risk and the cost/benefit ratio which each alternative offers is studied.

Figure 10. Examples of temporary barriers. Removable (Source: CAG Canalizaciones), stackable (Source: Flood Control International), collapsible (Source: Aggéres), inflatable (Source: Tandem HSE).

5. Pilot cases for adapting to flood risk: examples

Resilience to flooding: Fraga (Huesca)

Fraga (Huesca, 14,979 inhabitants) is a stark example of urban occupation of a flood plain. The locality has recorded recurring river surges, notable among which are the 1982 event and recent, less severe incidents in 2010, 2013 and 2018. In response to this situation, Special Amendment No. 50 of Fraga's City Master Plan (PGOU for the Spanish) brings limitations regarding flood risk into the municipal regulations.

In this case the methodology has been used which features in the guide named *Assessment of the resilience of urban population centres to flood risk: networks, urban systems and other infrastructure,* to find out which are the critical items which, if they ceased to be operational, might jeopardise the functioning of the rest of the urban network. Based on the mapping information available from the Download Centre at the National Geographical Information Centre (CNIG for the Spanish) we can obtain the inventory of Fraga's networks, urban systems and other infrastructure. Superimposing these on the hazard maps available from the SNCZI allows us an overview of the locality's adaptation requirements.

New uses that are compatible with floodability levels in the zones most at risk are suggested to boost resilience. On the other hand, several elements of the water supply and drainage/sewage network, power grid and transport system that need adaptive action are identified. There are also a large number of equipment items in the flood zone which could present crowded areas of population and hamper evacuation tasks in any emergency, which means they should organise their own self-protection plans. Likewise, through applying the concepts outlined in the *Sustainable Urban Drainage Systems* guide, assorted components of the landscape are flagged for potential integration with ecological connectivity criteria in urban development, with several examples of scope for benefit being described from a green and blue infrastructure standpoint.

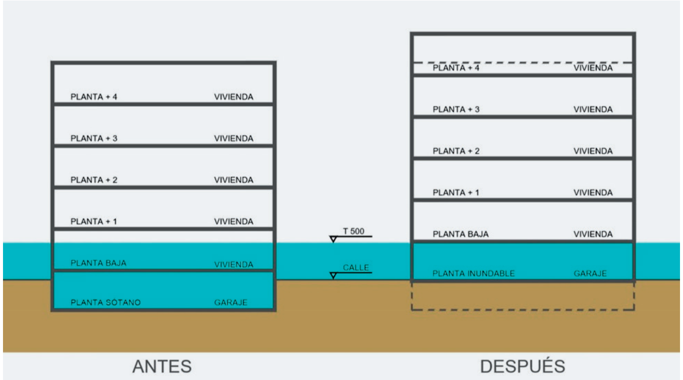


Figure 11. Regulation of the floodable floor established in Amendment 50 of the PGOU. Essentially involves leaving the ground (floodable) floor for parking space and not for housing in multi-storey buildings of new construction, eliminating underground garages and also removing residential properties from the ground floor.
Source: Fraga Council.

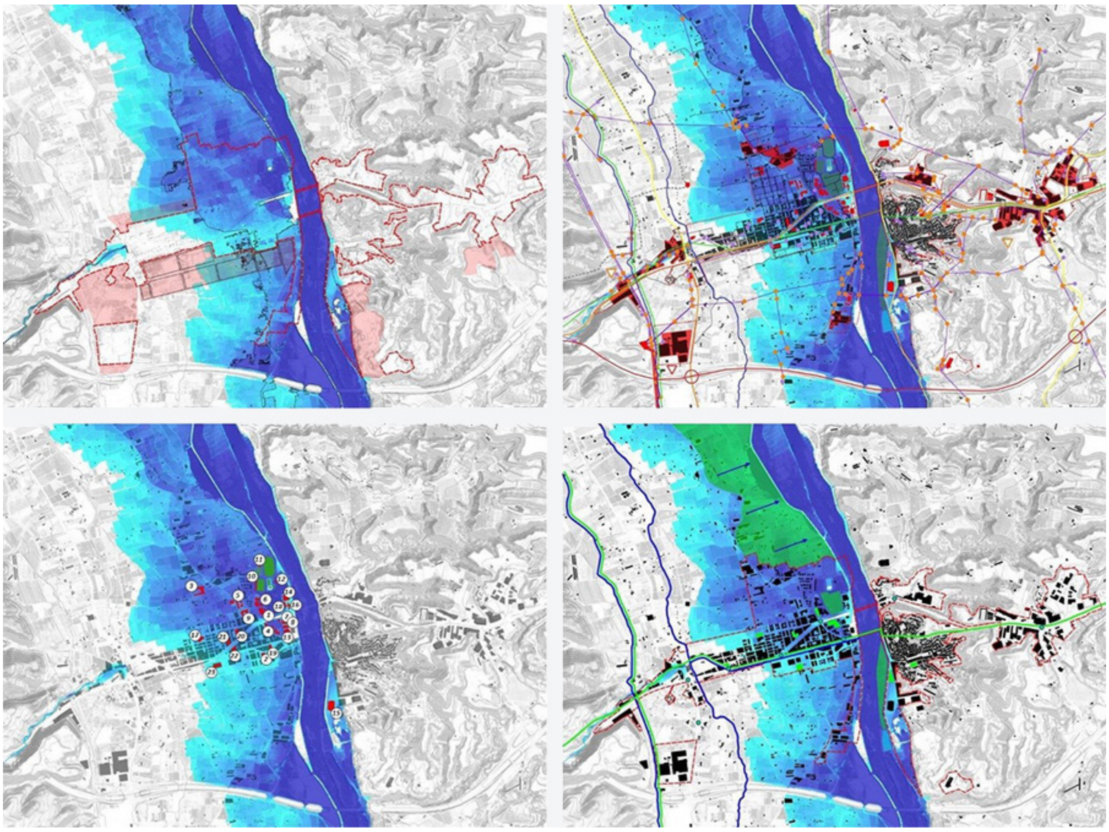


Figure 12. Urban resilience in Fraga: graphic analysis.
Source: Own research based on information from the CNIG and the SNCZI.

An illustrative economic appraisal has been made of the measured intended to prevent and withstand water coming into the health facility, the day centre and an infant and primary school. Given that these are basic buildings, the cost/benefit analyses return only modest results compared to other categories. Even so, they should be prioritised for adaptation in view of the vulnerability posed by the use made of them and the characteristics of those inside.

Recoletas Hospital/Carehome (Cuenca)

This is located where the river Júcar meanders through Cuenca, a zone prone to frequent flooding and often-varying river levels. The pilot study applies the concepts set out in the G*uide to reducing building vulnerability to flooding* and the guide offering *Recommendations for constructing and fitting out buildings in flood zones* as it seeks to diminish the building's flood risk by consummating the courses of action in the *Project to lessen flood risk and enhance the ecological condition of the rivers Júcar and Moscas as they pass through Cuenca,* which proposes setting back the raised boundary on the right bank to yield more space to the river.

The visit allows determination of the points where water might enter and the potential flood damage. Firstly, the general sewerage network is on a level similar to the river surface, meaning that, when floods happen, it breaks down and there is a flow-back of waste water. The ventilation grilles in the outside flooring, the spaces hollowed in the façade that are vulnerable to breaking and letting in water due to hydrostatic pressure or the impact of water-borne items, as well as the entry ramps to the basements are other points that require adaptation. On the other hand, there are various facilities that would be compromised in the event of flooding which would put the vital services at the centre out of action.

Implementing non-return systems definitively addresses the set of problems associated with the sewage network. Furthermore, building low surrounding protective walls and parapets is advised, as well as installing collapsible hydraulic floodgates built into the flooring. Lastly, the electricity, air-conditioning and domestic warm water systems, as well as the oxygen supply and other vulnerable equipment need to be moved upstairs.

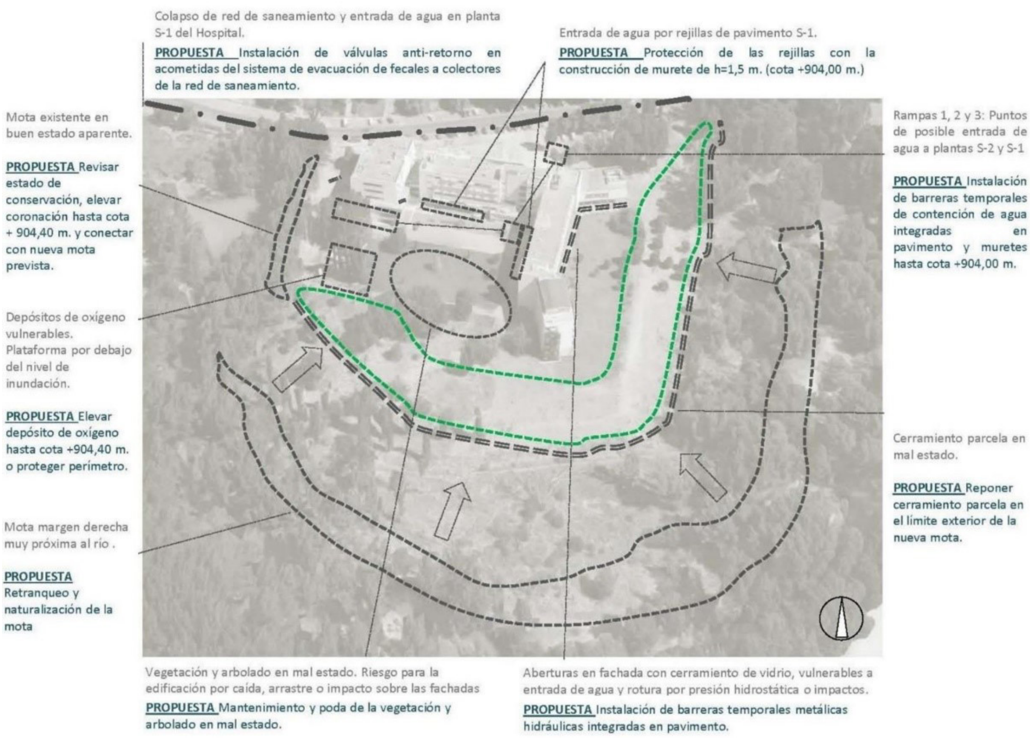


Figure 13. Cuenca pilot case: diagram summarising the proposal.

The new raised boundary protects the building up to the flood with a 25-year return period. For bigger surges, supporting adaptive measures have to be tackled. The estimated loss that would be generated by a river surge that reached the building amount to 920,000 euros, whereas the approximate cost of the measures is 197,000 euros.

Cebolla Town Hall (Toledo)

The municipality of Cebolla (Toledo, 3,263 inhabitants) has suffered several bouts of flooding over the past decade. Notable for its severity was the event on 8 September 2018, where the loss incurred meant for Consorcio de Compensación de Seguros opening 173 case files and represented a cost of 639,180.28 euros. The predominance of olive and fig-tree farmland upstream, with a steep slope and no measures to control the run-off and erosion, gives rise to dramatic changes in fluvial dynamics. On the other hand, the underground canalization of the Sangüesa stream and its lack of ability to run through the urban stretch of its course cause a build-up of items that block it and make it overflow in situations where there is a sudden increase in the volume it has to carry.

Cebolla town hall is located in the high street of the main population centre, where the steep slope causes water overflows to run at great speed. It is a basic building with loadbearing brickwork walls and wood slabs but, in the event of a flood, certain emergency protocols are triggered there, which means that if it is out of action, this could lead to indirect loss as regards the municipality's activities.

If we assume that any river surge will bring water into contact with the façade of the building, it is suggested that temporary barriers are used at the six entry points to the building to resist against water coming in. A possible solution is to deploy devices that consist of a steel frame that opens up over a horizontal and vertical plane and is encased in a neoprene covering to form a water-tight seal. These are easy and quick to set up and remove and can be fitted to a range of measurements. They need to be adjusted to ensure they are waterproof but they do not need any previous construction work. Installing non-return systems is also recommended.

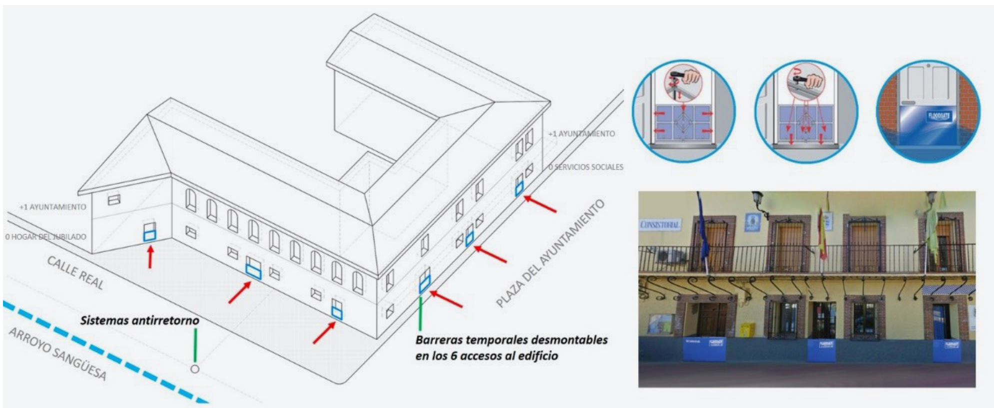
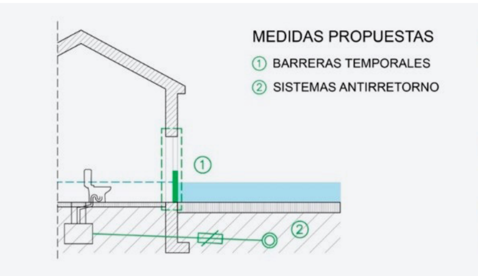


Figure 14. Cebolla pilot case: diagram summarising the proposed solution. Inset: removable barriers (Source: CAG Canalizaciones) and an example of how they are used with the building.

The package of measures costs roughly 7,500 euros. If we apply the methodology described in the guides, which factors in damage and its frequency, cumulative losses over 30 years are estimated to be over 80,000 euros. This gives us a cost/benefit ratio of 1:10.7.



SITUACIÓN ACTUAL	T=10	T=100	T=500
Altura de agua (m)	0,25	0,4	0,5
Probabilidad anual	0,1	0,01	0,002
Daño	14.750,00 €	23.600,00 €	29.500,00 €
Daño incremental	737,50 €	1.725,75 €	212,40 €
Daño anual medio			2.675,65 €
Daño 30 años			80.269,50 €
PROPUESTA DE ADAPTACIÓN			
BARRERAS TEMPORALES	4 barreras desmontables 1 x 0.68 m		3.000 €
	2 barreras desmontables 1.5 x 0.68 m		2.500 €
INSTALACIONES	Sistemas antirretorno en sanitarios		2.000 €
COSTE ESTIMADO TOTAL €			7.500 €
Reducción teórica del riesgo			100%
Beneficio/Coste			10,7

Figure 15. Cebolla pilot case: cost/benefit analysis.

Los Alcázares Town Hall (Murcia)

The municipality of Los Alcázares (Murcia, 15,674 inhabitants), which is on the shore of the Mar Menor, a Mediterranean lagoon, has recently suffered several flood events which have resulted in heavy property and economic losses. Its town centre is in the area where the La Maraña ravine and several run-off and downpour overflow beds meet, which causes water to enter over a broad surface with no clearly-defined main channel. Moreover, the municipal district borders to the south with the El Albujón ravine, which overflowed during the event of 12 September 2019. The man-made disturbance to the landscape associated with farming and urban development has increased the vulnerability of the local area to flood risk. The situation is aggravated by phenomena such as cut-off (i.e. closed upper-level) lows and the higher frequency of events of this kind owing to climate change. This complex problem calls for integrated strategies which take into account resilience on several scales (building adaptation, hydraulic construction work, green and blue infrastructure, etc.) and also contribute to protecting and recovering the Mar Menor.

Los Alcázares has various different public features that are located in a flood zone. These include the town hall building, which already suffered a loss to a value of nearly 1 million euros in the event in September 2019, most of which focussed on the two underground carpark levels. Flooding of such areas is a recurrent phenomenon in flood events, for which reason the pilot case offers a scalable solution that can be reapplied to similar situations. It also allows us to show how pinpointing water entry points and taking relatively straightforward and inexpensive steps can prevent very serious losses.

The proposed solution centres on installing temporary barriers at the entrances to the parking area. The idea is to use light 20-centimetre aluminium panels that are positioned between guiding-grooves and supports built into a concrete base. They are installed on top of each other and automatically form a seal, thus offering the greatest possible protection and allowing high levels to be reached. It is also suggested that temporary sealing devices are used where there are ventilation holes and non-return systems at the main connection to the sewerage network, as well as a set of back-up measures for the neighbouring building (a business and hotel premises) which has a carpark in common.

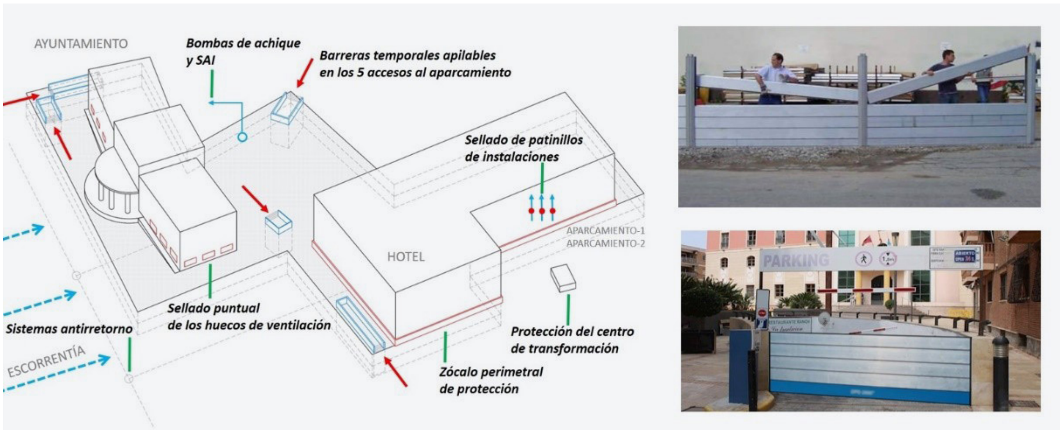
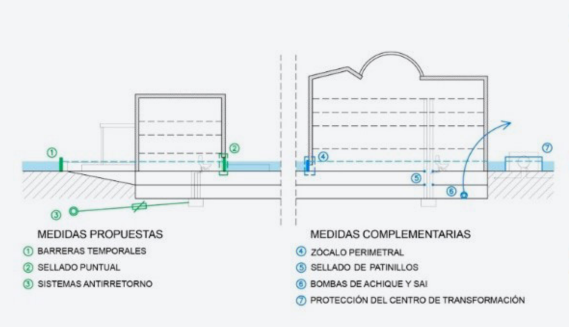


Figure 16. Los Alcázares pilot case: diagram summarising the proposed solution. Inset: stackable barriers (Source: CAG Canalizaciones) and example of use with the building.

The waterlogging of underground carparks is a recurrent theme in flood events and the loss involved is very high, regardless of how deep the flood becomes outside. This pilot case offers a scalable solution that can be replicated in similar scenarios and which also allows us to show how pinpointing water entry points and taking relatively straightforward and inexpensive steps can prevent very serious losses. The cost/benefit analysis yields very promising results, whereby an estimated investment of 55,000 euros would avoid potential losses amounting to over 4 million euros over a 30-year period.



SITUACIÓN ACTUAL		T=10	T=100	T=500
Altura de agua (m)		0,2	0,5	0,8
Probabilidad anual		0,1	0,01	0,002
Daño		964.600,00 €	964.600,00 €	964.600,00 €
Daño incremental		48.230,00 €	86.814,00 €	7.716,80 €
Daño anual medio				142.760,80 €
Daño 30 años				4.282.824,00 €
PROPUESTA DE ADAPTACIÓN				
BARRERAS TEMPORALES	3 barreras apilables 4.5 x 1 m accesos vehículos			30.000 €
	2 barreras apilables 2 x 1m accesos peatonales			10.000 €
SELLADO PUNTUAL	24 dispositivos de sellado puntual huecos ventilación			12.000 €
INSTALACIONES	Válvula antirretorno en acometida			3.000 €
COSTE ESTIMADO TOTAL €				55.000 €
Reducción teórica del riesgo				100%
Beneficio/Coste				77,9

Figure 17. Los Alcázares pilot case: cost/benefit analysis.

Multi-purpose building at the Gijón polytechnic school of engineering (Asturias)

On 11 June 2018, the multi-purpose building at the Gijón Polytechnic School of Engineering (Asturias) experienced a flood that derived from the overflowing of the river Peñafrancia, the surfacing of underground water and the heavy rains at the site. The occupation and narrowing of the flood zone, as well as a car-oriented urban development model which gives rise to additional obstacles and makes the ground water resistant, have created high-vulnerability conditions. This situation is currently aggravated by an upturn in the duration and frequency of strong storm events.

Given the complexity of the building, there are a whole host of potential water-entry paths. There have been notable rises in water via the small yard areas of premises due to the flooding of the space below the suspended flooring, which has occasioned large-scale loss across the entire floor-level.

The priority recommendation is to avoid the water reaching the building if there is a river surge by means of unbroken solutions that insulate its perimeter. If these should not prove feasible, an inventory should be made of all the vulnerable points and a complex programme devised consisting of one-off measures that is aimed at resisting against the entry of water. In this case, if any of the interventions fails or unforeseen points of entry appear, the proposed solution would be rendered invalid. On the other hand, given that the building is where significant research activity takes place and contains some very high-cost equipment and facilities, it is advisable to relocate the big-ticket items on higher floors that are not exposed.

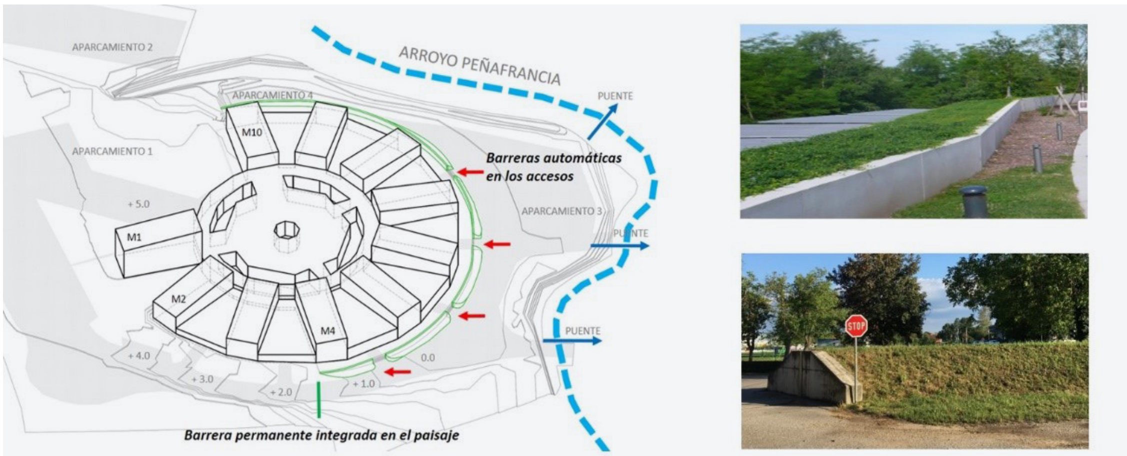
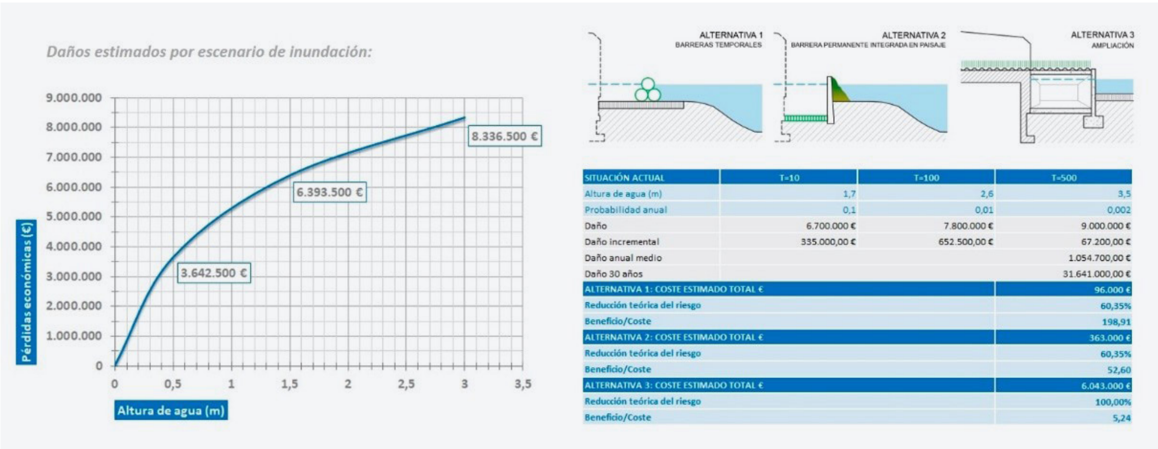


Figure 18. Gijón pilot case: diagram summarising alternative 2. Inset: examples of permanent barriers blended in with the landscape.

During the 2018 event, up to 80 centimetres of water flooded the ground floor of the building, causing estimated damage of 4.5 million euros. With no adaptive work, estimated losses over 30 years would be in excess of 30 million euros. Using inflatable temporary barriers, which are inexpensive, versatile and easy to install and store, offers a very advantageous cost/benefit ratio (of around 1:200). Nonetheless, they are dependent on both the action protocols working properly and a high degree of uncertainty with respect to the early-warning systems on account of the characteristics of the drainage basin. Another option, which is more costly, is building a permanent wall or barrier whose impact on the environment and the landscape can be offset by a response mix that combines engineering and nature-based solutions. This would be rounded off by installing automated barriers activated by means of sensors or water pressure at the access points. Lastly, a resilient building extension would be far more expensive but it would sort out the problem while also providing an increase in the school's useful area. This is nevertheless subject to the limitations that can be inferred from Royal Decree 638/2016 of 9 December.



SITUACIÓN ACTUAL	T=10	T=100	T=500
Altura de agua (m)	1,7	2,6	3,5
Probabilidad anual	0,1	0,01	0,002
Daño	6.700.000 €	7.800.000 €	9.000.000 €
Daño incremental	335.000,00 €	652.500,00 €	67.200,00 €
Daño anual medio			1.054.700,00 €
Daño 30 años			31.641.000,00 €
ALTERNATIVA 1: COSTE ESTIMADO TOTAL €			96.000 €
Reducción teórica del riesgo			60,35%
Beneficio/Coste			198,91
ALTERNATIVA 2: COSTE ESTIMADO TOTAL €			363.000 €
Reducción teórica del riesgo			60,35%
Beneficio/Coste			52,60
ALTERNATIVA 3: COSTE ESTIMADO TOTAL €			6.043.000 €
Reducción teórica del riesgo			100,00%
Beneficio/Coste			5,24

Figure 19. Gijón pilot case: cost/benefit analysis.

Marrón industrial estate (Ampuero, Cantabria)

The Marrón industrial estate, which specialises in manufacturing automotive parts, occupies the area between where the river Asón meanders as it passes through Ampuero (Cantabria, 4,219 inhabitants) and the Santander-Bilbao railway line, which is very vulnerable to flooding. The combination of heavy rains and the rise in temperatures that speeds up the thawing process in the mountains has triggered repeated surges in the past few years, most particularly on 31 January 2015 and 23 January 2019.

As a result of the serious event in 2015, the main company on the estate has implemented a contingency plan based on constant monitoring of the river course, special training for professionals and a set of self-protection measures (removable temporary barriers, non-return systems, bilge pumps and other specific actions) which made it possible to avoid business interruption throughout the 2019 event.

The problems involved concern overflowing and leakage through the retaining wall which borders on the left bank of the river as it runs through the locality. To support the measures that have been implemented this must be waterproofed and the possibility of raising it should be investigated, along with the potential repercussions of doing so by performing the relevant hydraulic modelling tests. Building drainage collection chambers is also advised to facilitate pumping efforts and allow the water to be emptied out effectively, as well as closing up the perimeter of the estate using temporary or permanent barriers to avoid water coming from other points in the case of extreme events.

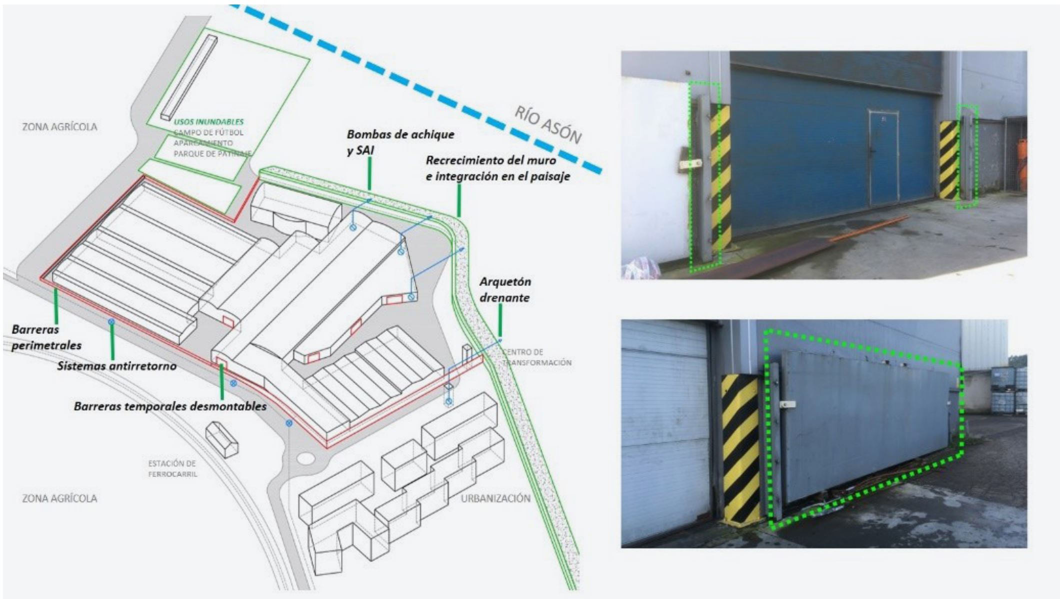


Figure 20. Ampuero pilot case: diagram summarising the proposed solution. Inset: removable temporary barriers.

During the 2015 event, the water reached as deep as 1.70 metres inside the industrial premises and caused 25 million euros of losses for the main company on the estate, including the damage to the buildings, machinery, facilities, goods and loss from business stoppage. The programme of measures implemented cost 145,000 euros; even though the protection it affords is not total and calls for a substantial effort in terms of planning and self-organisation, it presents a distinctly encouraging cost/benefit ratio of around 1:600.

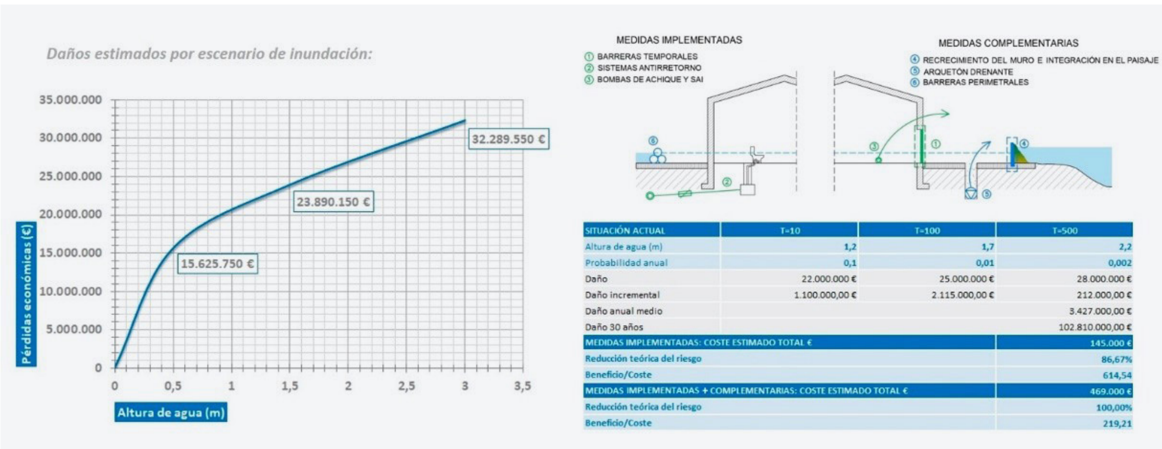


Figure 21. Ampuero pilot case: cost/benefit analysis.

Santa María de Huerta Monastery (Soria)

Ever since antiquity, owing to highly localised rainfall phenomena, Santa María de Huerta (267 inhabitants, Soria) has experienced surges in the volume of water passing through the gullies that flow into the river Jalón, which produces flash floods that bring serious consequences for the town centre. Farming-related transformations to the drainage basin and the presence of both artificial hindrances and hydraulic construction work that lacks capacity aggravate the problem today.

The Santa María de Huerta Monastery is an example of Cistercian architecture and was built between the 12th and 16th centuries. It was listed as a site of cultural interest, when it was graded as a monument, and is a key part of the cultural heritage of Soria and Castile-León. On 23 June 2015 the collapse of the Tejar gully broke the perimeter wall going through the cemetery, although there was only limited damage to the monastery. Another event on 9 September 2018 again knocked down the enclosure, which caused water to burst inside dragging along stones and other objects with it. Inside the building the water rose to over a metre deep in the church, refectory, hall of the converts, cloisters and other rooms. At the same time the flood affected several refitting and digging undertakings.

Even though the site of cultural interest embraces the entire premises, the pilot case considers studying compatibility between protecting cultural heritage and floodability by differentiating between and prioritising the separate elements. The idea is to avoid water coming into contact with the monastery, the cemetery and the archaeological remains so as to ensure their preservation and to accept the controlled flooding of a portion of the premises in the event of a surge. This way any sudden bursting of the wall that might speed up the water current and the damage caused is prevented, while this works in favour of hydraulic transparency by flattening out the flooding over a surface area so that the flow has been weakened by the time it arrives at the town centre.

After the 2018 event, a package of emergency measures valued at 400,000 euros was established, including (among other repairs and preventive action) installing floodgates in the perimeter wall to evacuate the water from inside the enclosure, building a metal wall to stop the water touching the building and upgrading the drainage.

Figure 22. Santa María de Huerta: implemented measures.

6. Conclusions

The *pilot cases for adapting to flood risk* allow the following general conclusions to be drawn:

- In Spain, flooding represents the natural risk that causes the most significant harm in terms of both property and human life. In light of this, adapting buildings can make a substantial contribution to keeping economic loss down and boosting the safety of those inside.
- These measures should not be taken to be in isolation, but instead within the context of integrated strategies that allow us to increase resilience and face up to future hydro-meteorological determinants. As a means of complementing long-term territorial transformations, adapting buildings offers ready answers to events for which no response capability exists in current circumstances.
- Land planning and exposure reduction in cities and communities represent the main preventive measures, although investing in these kinds of palliative measures, which are relatively inexpensive and straightforward, can be a way to avoid very severe losses.
- Dissemination on all levels is key to fostering a risk culture. Shared responsibility and both public and private commitment must be encouraged, thereby involving all stakeholders and promoting incentives to stimulate adaptation.
- Cost/benefit analyses return highly favourable results for certain case types, such as underground carparks, where a small investment avoids many forms of loss, or research centres and industrial estates, given the high economic impact of business interruption and because they are locations where very costly equipment is kept.
- Strategic infrastructure which, if put out of action, could compromise the rest of the urban network; the components allocated for sanitation, public residences and teaching centres, on account of the vulnerability posed by their purpose and the characteristics of their occupants; institutional buildings where specific emergency protocols are triggered; or the cultural heritage, given the importance of what it symbolises and the identity value it has, must also be adapted.
- Cost/benefit analyses must therefore be rounded off using new qualitative and quantitative indicators and factor indirect benefits from adaptive measures into the appraisal, including new environmental, economic and social values.

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Climate change on the coast and adaptation measures

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The challenge which climate change poses for the coast

The evidence of the impact of climate change on both human activities and ecosystems is stark. It represents a challenging task to our society, which has become aware of the planet on which it lives and the delicate equilibrium that safeguards its present and future living conditions. The coast is the first line of defence against the effects of climate change on the oceans and is, perhaps for that very reason, all the more vulnerable to its pernicious effects. It thus transpires that on the coast we encounter an interesting store of proof of how society can implement adaptation measures satisfactorily.

As is already widely accepted and demonstrated by highly reliable studies, the global mean sea level (GMSL) is not only rising, but doing so at an increasingly brisk pace. The accelerated rate is significant, since it compromises our response capability by shortening the time available for developing adaptation measures. Moreover, apart from this set of problems, there is evidence of an increase in extreme phenomena along the coast. These coastal phenomena are associated with meteorological tide levels and storm surges, and can be categorised within the general concept of extreme sea levels (ESLs).

Such exposure of the coastline to the effects of the rise in the GMSL and ESLs is even greater on account of determinants that are not wholly climate-related, such as the trend toward human overpopulation on the coast or anthropogenic land subsidence[1]. It is precisely this non climate-related component which makes local dependence very strong and means that adaptation studies have to be ad hoc and individualised down to physiographic unit scale.

Coastal ecosystems are characterised by presenting a certain degree of difficulty when it comes to discerning the origin of impacts. In general they will be affected by a blend of factors that relate to both the increase in indicators of mean sea level (MSL) and ESLs, and the set of socio-economic activities that take place offshore and onshore. Even in zones relatively far-removed from the coast, anthropogenic action can impact on the system. As a clear sign of this, for example, we could mention sediment management in hydrographic basins.

Protection measures consist of developing structures that reduce exposure to flooding and lessen the frequency of adverse impacts associated with ESL return periods and the rise in the MSL. Within this category there is a wide range of possibilities, so the right solution will depend on a multi-disciplinary analysis that includes morpho-dynamic, construction-related, functional, administrative or environmental determinants.

If coastal protection is properly designed, it is very efficient in reducing damage associated with ESLs and so, even if it should prove necessary to make something of an investment in them, this effort is more than repaid by the lower expense on repairs or environmental restoration.

(1) The sinking of ground caused by extraction of sub-soil fluids (water, hydrocarbons, etc.).

We should not lose sight of the fact that human activities on the coast can exacerbate its exposure and vulnerability, with the result that, given a rise in MSLs and ESLs, there is a higher risk of adverse effects from coastal floods. In fact, in the present context it is hard to distinguish whether the exposure of a zone to coastal flooding is attributable to climate factors or direct man-induced causes, which amounts to a complex, though necessary challenge to tackle with the goal of proposing and implementing effective adaptation measures.

Another aspect to bear in mind is that along certain sections the coastline is already under a great deal of pressure and highly confined, which means that it is likely to have lost its ability to adapt to climate change naturally via demographic processes, such as progressive migration inland, to offer one example. It should also be stressed that the ecosystems on the coastline play a very important role as natural shields against coastal storms.

Lastly, another feature typical of the coast is its high dependence on the local factor, which can give rise to substantial variations relative to global estimates of the various different oceanographic variables of interest. This is likely to be the case of the local subsidence in many deltas caused by human activity for example, which ought to be taken into account to be in any position to make proper projections of the rise in the MSL in the zone and thus obtain adequate scenarios for suitable projection of adaptation measures.

Coastal management in reply to climate change

Responses to the impact of climate change in the form of adaptation are highly diverse across the world, although they have generally been implemented in reaction to present risks or natural disasters. We should remember that we need a long-term outlook in risk management as regards the coast to optimise resources in developing adaptation measures.

In the long term, the climate values that are chosen to define what action needs to be taken to reduce the vulnerability of the Spanish coast rely very heavily on the climate scenario considered. In addressing this issue, the United Nations Intergovernmental Panel on Climate Change (IPCC) looks at four scenarios (Representative Concentration Pathways or RCPs) which serve as a basis for determining the strategies that correspond with different measurements of radiative forcing[2] in relation to greenhouse gas (GHG) concentration levels (Figure 1).

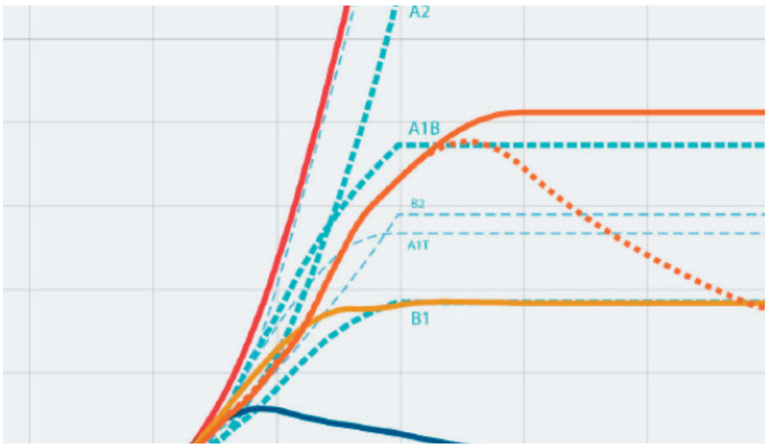

Figure 1. Emission scenarios according to the IPCC.

There are also nationally-promoted developments to build the long-term view into management of the coast. Suffice it to mention the recent work by the Directorate General for the Coast and Sea on updating the databases for climate change projection on the Spanish coastline or for climate change adaptation strategies for Spain's coast.

(2) Radiative forcing is the difference between insolation (sunlight) absorbed by the Earth and energy radiated back to space. When the chemical composition of the atmosphere changes as a result of GHG emission, the radiative equilibrium is altered by positive radiative forcing, which causes temperatures to rise since the Earth receives more energy from the sun that it gives off into space. This energy difference is that absorbed by GHGs.

The project titled "Designing the methodology and databases for projection of the impacts of climate change on the Spanish coast" develops regional climate change projections for marine variables that are needed for monitoring and assessing impacts on the coastal and marine zone. To summarise, to develop this new database seven global models were used, which were subjected to dynamic downscaling[3] to reach local scales, with climate bias correction made for them one by one, thus enabling variables to be obtained for swell, meteorological tide set-up, sea-level rise and surface temperature for two RCP climate scenarios, where one relates to emission stabilisation (RCP 4.5) and the other one would imply a high emission level (RCP 8.5).

Nor should we overlook the new developments in remote sensing for coastal monitoring, which are certain to revolutionise our knowledge of the state of the coastal strip and how it evolves. From these we will be able to obtain morphological variables on the coast with a very high temporal frequency compared to the data collection which we used to be able to achieve using traditional methods. In this area the EU's Copernicus programme will play a key role in promoting products that are useful for managing the coast via its various different services.

Adaptation measures

Having incorporated long-term analysis of climate change effects into coastal management (when our scope for taking action with respect to them is likely to be only limited within a globalised context), we should undertake the adaptation measures required to reduce the risk of climate change effects on the coast. Here, according to the IPCC adaptation measures can be classified into: (a) no response, (b) advance, (c) protection, (d) retreat, (e) accommodation and (f) ecosystem-based adaptation, Figure 2.

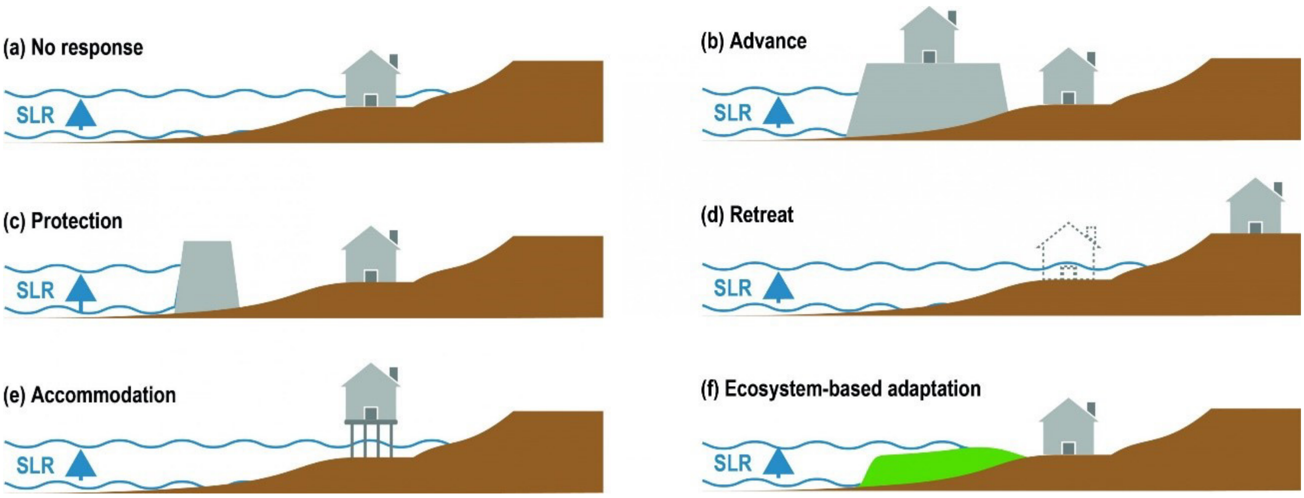

Figure 2. Adaptation measures.
Source: Special Report on the Ocean and Cryosphere in a Changing Climate. IPCC.

All of these adaptation measures to respond to the rise in the MSL and ESLs have synergies and allow a range of actions for sequential and integrated adaptation to climate change on the coast. The IPCC actually recommends hybrid solutions for adapting the coast to climate change so that it is possible to carry out sequential and integrated planning.

(3) Downscaling is a process to infer high-resolution information from low-resolution variables, i.e. to obtain information with greater spatial and temporal detail from the results of a larger-scale model. In dynamic downscaling, the output from a global model is fed into another, regional model with higher spatial resolution, which enables simulation of local characteristics with a greater level of detail.

Both protection and advance are economically efficient, mainly in established urban zones, although they should often be accompanied by other measures that are aimed at cutting down the increase in exposure in the very long term and which, generally speaking, relate to territorial planning, safety and environmental protection.

When there is enough space to implement them properly, i.e. on non-constrained coasts, ecosystem-based adaptation measures can be effective. These measures also have additional advantages associated with carbon sequestration or improved water quality. Furthermore we should not lose sight of the fact that certain coastal ecosystems can, under certain conditions, migrate landwards, which helps bring about natural adaptation of them to sea-level rises.

On the other hand, accommodation measures are very inexpensive and effective. In fact it could be said that in most cases it is more economical to invest in measures of this type than to opt for no response. Nevertheless, it is a good idea to be aware too that such solutions do not act on protection elements, which means that they lose their effectiveness over time.

Retreat is a measure with a high social impact that, in principle, could only be entertained when the risks of destruction are very high and in zones where no high population density exists. As for advance, this measure is especially advocated when there is no space going inland and big benefits can be obtained in seaward implementation, although this also means an increase in exposure to the effects of a rise in the MSL and ESLs.

In the case of opting for no response, coastal flood damage in the environment can be expected of between two to three times more than current levels by the year 2100 owing to the increase in the strength and frequency of ESLs, according to the latest IPCC report. This option must always be considered, given that it allows us to assess the study of alternatives financially, as the benefit gained can be quantitatively estimated if there is investment in adaptation measures. In Figure 3, we can note the increase in damage in Spain's coastal zones according to seafront in the case of no response.

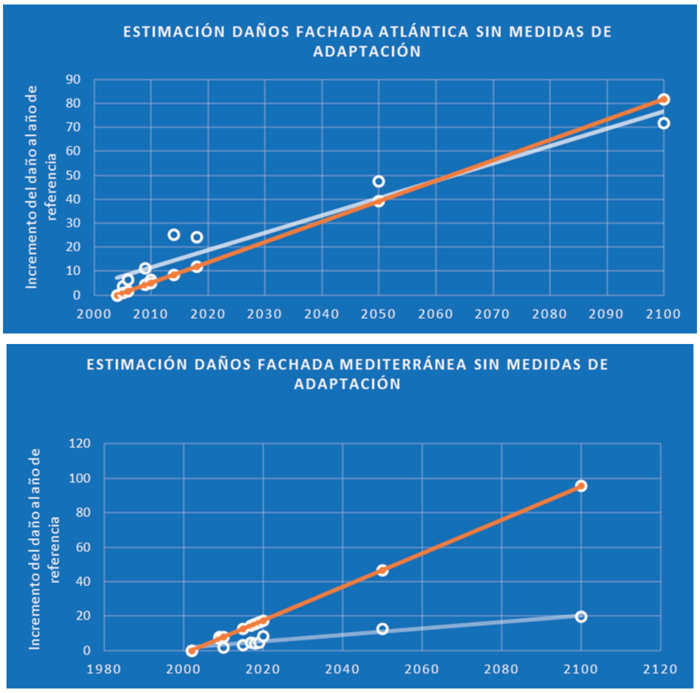

Figure 3. Loss estimations in the Spanish Atlantic Coast (up) and in the Spanish Mediterranean Coast (down) as % increase with respect to the reference year (ca. 2000). Blue line: trend according to the IPCC report; orange line: trend according to data on storm damage. The study has a purely qualitative value. The model has assumed that there is temporal independence between statistical values and that the sample is homogeneous on all seafronts. It does not take into account bias that relates to decision-making, such as adaptation measures.

Advance measures basically consist of reclaiming land from the sea by creating new land beyond the coastline. This measure is considered in some countries as an adaptation measure and is therefore included in the IPCC classification. It generally means that there is no other possible alternative for avoiding serious socio-economic harm. It is particularly taken into consideration in densely populated zones where there is no setting-back option since these are hemmed in on the coastal fringe. An example of this kind of action is the Dutch *polder*.

Protection measures consist of developing structures that reduce exposure to flooding and lessen the frequency of adverse impacts associated with ESL return periods and the rise in the MSL. Within this category there is a wide range of possibilities, so the right solution will depend on a multi-disciplinary analysis that includes morpho-dynamic, construction-related, functional, administrative or environmental determinants.

If coastal protection is properly designed, it is very efficient in reducing damage associated with ESLs and so, even if it should prove necessary to make something of an investment in them, this effort is more than repaid by the lower expense on repairs or environmental restoration.

Designing coastal protection is complex because other factors can become mixed in with flood problems on coastal zones that have nothing to do with climate change *per se*. A clear risk linked to this fact is that of designing adaptation measures and plans aimed at resolving the current erosion problem but which fail to take into account future sets of climate change problems.

Besides other climate factors, a significant consequence of the fact that the GMSL is rising and that this is accelerating is that ESLs, which had thus far been exceptional according to available historical data and had return periods of the order of 100 years, will become frequent by the year 2100. Moreover, this is true for all of the RCPs which the IPCC considers and is very dependable. In terms of coastal protection design, this means that storms on the coast with a return period within the acceptable safety limits of any design could suddenly fall outside these parameters on being impacted by ESLs with unaccustomed frequency.

We could deduce if this is in fact happening using certain indicators. The increase in ESL frequency should be reflected in an increase in expenditure on coastal restoration. In this respect, even though a larger sample is required and there are significant determining factors, it is actually being observed that the impact of storms on the coast is increasing on every seafront on the Spanish coastline (Figure 3).

This shift in the time series for ESLs, which influences the determination of extreme regimes and, therefore, establishes design variables associated with return periods, must be taken into account when designing coastal protection. Ignoring this fact would mean making investments that do not adequately address coastal zone exposure to climate change effects and which therefore do not represent genuine adaptation measures.

Within the scope of protection measures, we have two clear options: coastal structures and artificial sediment supply. These two measures can be combined with each other in certain cases.

Coastal structures normally consist of dykes or seawalls that provide stability for a physiographic unit that is not in equilibrium, thereby reducing erosion of it and thus allowing greater defence against floods.

Normally, on the coast, unlike with harbours, there are generally no vertical dykes, except in the case of waterfront promenades, so we usually come across solutions of the sloping-dyke kind. This solution enables stabilisation of the sediment dynamics in a zone in disequilibrium. Changes in ESLs can cause hitherto stable systems to lose equilibrium, which is conducive to sloped dykes being used, especially in populated zones where other measures are not efficient. It should also be borne in mind that on coasts in a current state of disequilibrium on account of anthropogenic effects, changes in ESLs can exacerbate such problems and thus speed up its disintegration.

The other alternative would be artificial replenishment of sediment systems. In this case a careful analysis of the current and future sediment dynamics is required to determine whether the filling will be stable and if regular replenishment is needed. A key determining factor in this solution is whether it is necessary to perform regular replenishment, which generally tends to be common on the Mediterranean seafront. To be able to perform regular replenishment effectively, it is necessary to be sure of being able to carry this out at the right time, although this is sometimes not possible due to the fact that successive environmental assessments have to be overcome, which delay action, or financing has to be available, which makes it hard to press ahead in a context of annual budgets and restricted multi-year funding allocation.

Figure 4. Beach stabilised using a system of dykes and seawalls. Sitges (Barcelona).

A good example of how to proceed with this type of solution can be found in Holland in the case of the sand engine *(De Zandmotor*), which is a replenishment solution that is applied along the southwest coast of the Netherlands. (Figure 5).

The Dutch sand engine is a fine example of "building with nature". Taking advantage of the courses predominantly taken by sediment, the sand (which was obtained from sea-dredging) is gradually spread along the Dutch coastline. This has a useful life of 20 years and is intended to combat the erosion of this zone on the Dutch coast by the ESLs caused by climate change.

Figure 5. De Zandmotor. Netherlands.
Source: Dutch Directorate-General for Public Works and Water Management (Rijkswaterstaat).

Retreat reduces a population's exposure to storms but entails a large social impact from having to move not only the infrastructure, but also the population. This is nevertheless not a novel solution, given that this type of action has already been taken in other fields, such as in building dams and reservoirs to achieve hydraulic regulation.

This option could be considered in zones where the population and its density are low and the risks of coastal damage are very high. On the other hand, it does not appear to be a feasible solution in densely populated zones, where it is better to plump for other alternatives. Whatever the case, owing to its high impact, this option is not usually taken into consideration.

Even so, it should be pointed out that, in terms of Spain, Law 2/2013 on protection and sustainable use of the coastline did in a way examine this option by bringing into Law 22/1998 on Coasts the declaration of land at serious risk of retreat where it is not possible to restore it to its previous state by means of natural processes. The range of options for such land declared at serious risk includes the termination of title for those government concessions that the sea reaches, which would in effect mean the retreat of occupation of this type in coastal zones, albeit on a merely occasional basis.

The accommodation option basically consists of assuming that flooding is unavoidable and that we just have to live with it. This option embraces several alternatives for action, such as, for example: raising buildings, changes in farming culture, using crops that are adapted to a saline environment, or early warning systems. It has to be said that this option includes actions that fall within what are known as resilience measures.

In the context of this type of resilience measure aspects would become involved such as developing evacuation protocols and systems to alert the population, managing land uses, social education and building resilient infrastructure and buildings.

Figure 6. Example of resilience measures in buildings: Watertight modular closing doors in enclosing walls.
Source: Guide to reducing the vulnerability of buildings to flooding. (CCS, 2017).

Resilience measures do not act on existing protection elements, meaning that as they deteriorate, their efficiency will decrease. Mention should also be made of the fact that resilience measures can be combined with other adaptation alternatives to decrease exposure to ESLs.

Finally, we come to ecosystem-based adaptation measures. It should be clarified that although certain protection measures can be thought of as ecosystem-based adaptation measures, they have traditionally been considered as coastal protection measures. This is the case for beach replenishment, which are an example of "building with nature", as we have mentioned earlier.

The general concept of ecosystem-based adaptation measures is predicated on restoring coastal eco-systems so that, other than having an environmental role, they perform a structural function as coastal flood protection elements. Another example of this kind of action is dune regeneration, where dunes act as a natural beach defence and can both nourish the system with sand when it is eroded and migrate inland when there are rises in the sea level.

For an ecosystem-based adaptation measure to be successful there has to be enough space and a certain distancing from polluting activities or sources that might have an impact on the system and both threaten its efficacy and prevent it from operating as it should. For example, on busy beaches, marking out paths to reach the sea and restricting access to dunes in the zone where dune regeneration is intended is really decisive, given the fragility of the eco-system in relation to people passing through.

Certain coastal eco-systems, such as mangrove swamps and marshes can relocate inland naturally in response to rises in the MSL. Even so, to do this, there has to be enough space and the rise in the sea level needs to be gradual, which means that any acceleration in the rising process will compromise this ability. Whatever the case, such steady migration helps these natural barriers to be potentially highly effective against climate change, provided that the conditions referred to are in place.

Another aspect to take into account in the response by coastal ecosystems to climate change would be the biophysical variables that can affect them and make them more vulnerable to changes in the MSL and ESLs. Thus there should not be any possible sources of pollution in the zone to be regenerated that arise, for example, from spills or waste that alter concentrations of nutrients and produce eutrophication in the system that can upset its equilibrium. Moreover, the biophysical values associated with an ecosystem can in turn be affected by climate change and such potential variation must be borne in mind to allow proper analysis of how effective it is as a coastal adaptation measure.

Figure 7: Maspalomas dune system. Gran Canaria.

Barriers to adaptation

Even if all the information is available and the impact of climate change is certain and the technology is on hand to implement measures and solutions, a wide variety of barriers to adaptation exists. These barriers encompass any kind of challenge or restriction that delays or interrupts adaptation measures. To overcome them, they first have to be identified and then sufficient effort must be spent on surmounting them. To put this into better perspective, it has to be understood that these barriers can range from irrational human behaviour to a lack of funding from the government bodies responsible.

Indeed, the government bodies charged with tackling the effects of climate change often face financial, technical and personnel limitations on adequate implementation of plans, programmes and projects in such a complex context as climate change. On the other hand, the existing decision-making culture within organisations can represent another major hindrance, such as when adaptation to climate change is approached as a purely environmental matter rather than a cross-cutting issue that in reality affects all areas of society. Legislation in itself can also be a barrier to adaptation and, among other things, can stop measures being taken due to the consequences of liability that might arise.

These are just some of the barriers of this kind, but, as has already been said, the spectrum can be a very broad one. As regards this issue, certain specific barriers can be identified on the coast that relate to legislation or adaptation measures. We now go on to outline two examples of these that originate from Spanish experience.

At EU level, the legislation that concerns coastal zones is mainly allocated between two major directives: the Water Framework Directive and the Marine Strategy Framework Directive (MSFD), since both include "coastal waters" within their scope. It is nonetheless necessary to point out that this is not the case at the Spanish level, where we have pioneering legislation on coasts as regards protecting them in the form of Law 22/1988.

Returning to the EU sphere, although it might seem that the coastal zone is covered by these two major directives and therefore benefits from the various initiatives promoted by the EU, the reality is otherwise. This is chiefly because the people who are at the helm of these initiatives are generally more closely linked to the realms of rivers or the sea, which are the dominant subjects in each of the directives, and both unwittingly and tacitly overlook those in charge of coastal affairs.

This implies additional coordination efforts for the European Union and the Member States, which means, in a situation where resources are limited, that the needs of the coastal zone are often not fully met and that the initiatives only adopted from the point of view of the rivers or the sea, with the coast relegated to supplementary status rather than being a core area in its own right. On this point, the general opinion of those in charge of the coasts is that Europe should move in the direction of specific legislation for the coast that features explicit services and lines of action.

Regarding adaptation measures, there is a barrier to implementing those that are aimed at protection, specifically in the area of beach replenishment. We must not forget that beach replenishment serves to solve a problem of disequilibrium brought about by the impact of various human actions, so it should be useful as a corrective measure where impacts of this kind are concerned. On top of this, climate change may exacerbate erosion of this kind and speed up the degradation of the coastal system.

In the case of hemmed in coasts, the most efficient option is protection and, moreover, when it is a viable option for solving the problem, replenishment has the added value of being "building with nature". Nonetheless, implementing this is running into certain difficulties associated with obtaining material for filling by means of marine dredging. Even though there have been satisfactory experiences involving land matter in replenishing beaches (mainly in the Canary Islands), this type of material is not viable on other Spanish coasts on account of the properties of the indigenous matter, which effectively makes dredged filling material the only option.

In this respect, there is currently no smooth mechanism for obtaining the necessary permits to use sea dredging and implementing the actions afterwards. We should remember that coastal ecosystems are delicate and that erosion or destruction of them affects precisely those species for which protection is sought. There is no doubt that impact analysis must view ecosystems through a broad lens and incorporate a long-term approach that enables a proper equilibrium between protection and adaptation. This means that protection measures must be taken, but the cost of these should always be assessed in terms of any increase in the vulnerability of the coastal system so that we can gauge whether the impact of timely action is compensated by the benefits gained in the long term as opposed to the alternative of no response.

The challenges we face with climate change are considerable, so implementing adaptation measures is complex. Yet, most of society has become aware of this challenge, which has fortunately helped to provide us with more guarantees than ever to surmount this. For some time now we have had a better knowledge of the effects and impact of climate change on the coast, as well as the technology required to adapt. Overcoming barriers to adaptation will only be a matter of political will and social effort, which will set us on the right path to protecting and conserving our valuable coast to the extent that this is possible.

Rain flooding in Spanish urban zones: a damage estimation model based on adjustment experience

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Introduction

According to the European Environment Agency (EEA, 2019), total reported economic loss from extreme climate events in Europe for 1980-2017 amounted to approximately 435 billion euros, of which 37 billion was in Spain. The Consorcio de Compensación de Seguros (CCS) estimates that roughly 50 % of the loss caused was insured. An illustrative figure is that the loss caused in Lorca (Spain) in the wake of the 2011 earthquake was estimated to be one billion euros, of which 50 % was insured, meaning that the relevant compensation was paid out (IDEA -Improving Damage assessments to Enhance cost-benefit Analyses- project, 2014).

Economic loss from flooding in urban zones is increasingly substantial in keeping with the socio-economic changes that occur, such as population growth and greater infrastructure density in cites the world over (UN, 2018). Flooding is the most frequent natural hazard, accounting for two thirds of loss driven by natural events in Europe. Warming from climate change is expected to intensify the hydrologic cycle, producing stronger and more frequent floods in many regions and consequently giving rise to economic loss. Even so, as the EEA suggests, the increased loss from flooding in recent decades could be partly attributable to urban development in floodable zones.

If we only look at pay-outs relating to buildings (excluding civil works and vehicles), 2018 spoke for practically 75 % of the total, being concentrated in commercial premises, stores and warehouses, and other risks.

This therefore confirms that commercial premises are the most vulnerable type of property to urban rainwater flooding.

This data highlights the significance of urban flooding from rainfalls and clearly shows a need for tools that help to estimate the damage that they can cause.

There are several different kinds of loss from flooding and they are classed in the literature as tangible and intangible, which can be further subdivided into direct or indirect (Velasco et al., 2016). Assessing the economic loss from floods (tangible loss) is one of the aspects that has traditionally been studied in the greatest depth. In particular, as regards urban zones the most prevalent analysis to date has concerned evaluating property damage.

Against a backdrop of rising flood damage in Europe, Directive 2007/60/EC of the European Parliament and of the Council on the assessment and management of flood risks was published, which obliges Member States to draw up, pass and implement flood risk management plans. This EU regulation was transposed into Spanish law via Royal

Decree 903/2010 on the assessment and management of flood risks. One of the measures included in the Flood Risk Management Plans (FRMPs) in Spain was the drafting of a “Guide to reducing the vulnerability of buildings to flooding.” (CCS, 2017).

This guide was intended to provide a better understanding of the consequences of floods and to encourage a commitment to risk reduction on the part of the public through a focus on decreasing the vulnerability of people and property as well as enhancing the resilience of exposed buildings.

Thus far, management plans have centred on river and coastal floods, which can in fact bring serious consequences for the urban zones reached by the flood. However, all cities are also exposed to pluvial flooding when the rainfall exceeds the designed capacity of their drainage networks on a more or less frequent basis. While it is true that the consequences of pluvial floods in urban zones do not tend to compromise people’s lives, addressing them is worthwhile to the extent that they imply economic loss. Moreover, forecasts suggest that rainfalls will be heavier as a result of climate change, with urban zones in particular standing to be worse off (Arnbjerg-Nielsen et al., 2013).

Estimating flood loss using depth-damage curves

There are several different approaches to developing flood damage assessment models. The common thread they have, though, is that they enable analysis of the efficiency of flood damage mitigation measures. Cost-benefit analyses are conducted to compare the cost of taking no action versus the loss avoided under certain adaptation scenarios. The models enable estimation of both the damage which would be caused in these adaptation scenarios and the associated avoided damages.

An essential difference among the various models is the scale they use: while some are based on aggregated uses of land, others focus on specific items (such as buildings or plots of land). The latter type offers greater complexity, since it is on a more detailed scale, whereas the first sort is more straightforward and yields quicker results for more extensive areas. The models on a detailed scale have the advantage of accurately defining the building density in urban zones, which is not the case with land-use models. Models based on Geographic Information Systems (GISs) provide an idea of the spatial distribution of damage in the zone being studied.

So-called depth-damage curves, also known as vulnerability curves, provide the essential basis for many of these models. These are mathematical functions that correlate floodwater depth for a property or given land use (depending on the scale of the study) with the damage caused.

The models are very sensitive to selection of these curves, given their peculiarities. Asset values have to be adjusted to fall in line with regional economic situations and property characteristics. Furthermore, actual damage to properties is not merely a function of floodwater depth alone, but also of other factors, such as the time of year when the flood happens, how long it lasts, water velocity, water-borne debris, and warning time prior to the flood. It is therefore clear that approaches based on depth-damage curves entail intrinsic uncertainty and that other factors beyond depth are influential in producing flood damage. In spite of this, taking floodwater depth to be a key factor in causing damage is very common practice.

These curves can be presented in relative or absolute terms and considering damage as a percentage of total property or expressed in monetary terms respectively. Whereas the first kind can be more easily transferred in space and time, given that they do not depend on the market value of the assets, the absolute damage curves call for regular recalibration to be made to factor in depreciation or inflation. But then again, the curves can be classified according to their construction procedure; specifically into those that are analytical, empirical or synthetic and even combinations of these types. The analytical ones are based on laboratory analysis resulting from monitoring the effects of variables such as water depth, flow velocity or flood duration. The empirical curves are constructed from gathering actual data on damage to properties based on survey campaigns. Then synthetic curves are the fruit of a theoretical study for a standard type of property on the assumption of it being representative of the zone being studied. This last group is mainly used when no actual data on flood damage is available.

These curves are constructed for different types of properties or land uses, depending on the working scale, and they tend to show, on the one hand, the damage to the building structure and, on the other, that to the contents. Damage to the structure relates to the building itself and the components of it that "are not taken away in the event of moving house", such as doors, the boiler, the flooring or the fitted carpet etc. On the other hand, damage to contents (furniture and fittings/equipment, stock, etc.) are the items that would be carried away if a person moved out of the house in question (McBean et al., 1988).

In Spain there are few depth-damage curve models, most being specific to certain regions, while there is only one for national coverage (Figure 1).

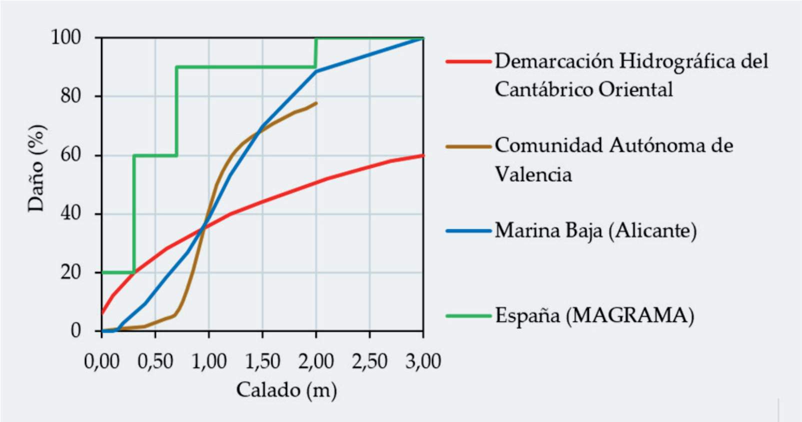


Figure 1. Depth-damage curves for different regions of Spain.

The RESCCUE project and Barcelona as a Spanish case study

The core aim of the H2020 RESCCUE project (http://www.resccue.eu/) (**Res***ilience to cope with* **c***limate* **c***hange in* **u***rban ar***e***as – a multisectorial approach focusing on water*) is to develop methodologies and tools to assess and manage urban resilience to climate effects. Three study cases are included where the various tools developed are implemented (Barcelona, Bristol and Lisbon), which have different characteristics and response capabilities according to climate change scenarios.

The RESCCUE project is coordinated by the company AQUATEC (SUEZ Advanced Solutions) and at Cetaqua, the Water Technology Centre (https://www.cetaqua.com/home). We play a major role, since we are the institution with the second biggest contribution. The project has 18 partners, notable among which are the three councils of the case studies, universities, and public and private companies in the urban water cycle and energy sectors. UN-Habitat is also taking part as a partner on the project with the goal of ensuring that implementation of the methodologies developed can be replicated in other contexts beyond those which have been studied in the context of the project.

Among other tasks, at Cetaqua, we carry out studies to assess the risks arising from potential climate effects on the city of Barcelona. One of the most exhaustive analyses is that of risks from rainwater –pluvial– floods, which are increasingly prevalent in metropolitan Barcelona. To illustrate this, here are some of the studies carried out:

- Drawing up mapping of risks to pedestrian and vehicular stability based on stability thresholds determined experimentally at the Institut Flumen (Technical University of Catalonia) (https://www.flumen.upc.edu/en).
- An analysis of the stability of the city's refuse and recycling containers during flood events (Martínez-Gomariz et al., 2020).
- Estimation of vehicle damage (Martínez-Gomariz, Gómez, et al., 2019).
- Development of a model to estimate direct property damage (Martínez-Gomariz, Guerrero-Hidalga, et al., 2019).

Damage caused by floods in Spanish municipalities in the specific case of Barcelona

The record of historical data on compensation paid by the CCS is of great value in managing catastrophe risks in general and flood risk in particular. The analysis of total historical pay-outs for building damage nationwide makes it possible to rank Spanish municipalities from most to least damaged, among other things. Figure 3 shows the 20 municipalities where buildings have had the most flood loss awarded compensation in Spain from 1995 to 2019.

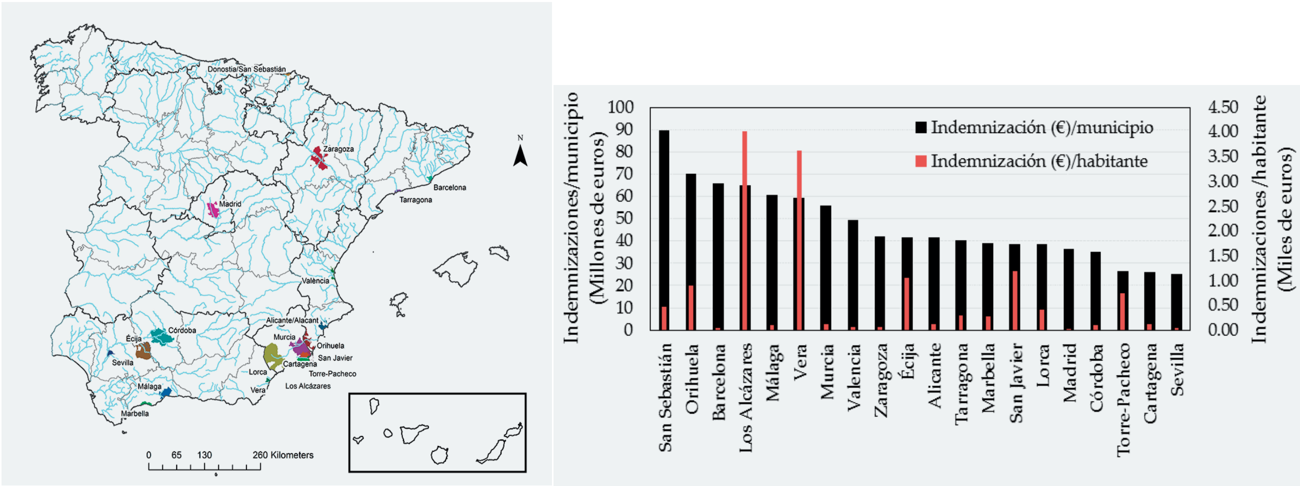


Figure 3. The 20 Spanish municipalities which had the most insured loss on account of floods (pluvial and fluvial) in 1995-2019. The values are for compensation paid out and provisioned by CCS as at 5 February 2020 using prices updated to 2019.

The floods which prompted these pay-outs may have originated from pluvial or fluvial events, since CCS' classification does not make any distinction between them. The geographical illustration clearly shows how the especially vulnerable municipalities are concentrated in the Mediterranean area. With some 75 million euros in compensation over the reference period, San Sebastian (Basque Country) is the most severely affected Spanish municipality with respect to the economic impact of flooding. Nonetheless, if we take average compensation per inhabitant, we could say that Los Alcázares (Murcia) is the municipality most vulnerable to floods.

In the city of Barcelona alone, total compensation paid and provisioned by the CCS as at 31 July 2019 and from 1996 to 2018 accounted for 43 million euros for industries, offices, residential homes and homeowners associations, vehicles and civil works, according to the classification used by CCS (Figure 4). In 2018 there were four episodes of heavy rains which caused significant loss in the city of Barcelona (Figures 4 and 5), with this year marking the third largest economic hit in terms of compensation over 1996-2018. Only 1999 and 2002 outstripped it, although, since then, several actions concerning the city's drainage supported the assumption that the situation had improved considerably.

If we only look at pay-outs relating to buildings (excluding civil works and vehicles), 2018 spoke for practically 75 % of the total, being concentrated in commercial premises, stores and warehouses, and other risks. This pattern is not a one-off and for all major flood events in the years under review over 50 % of total compensation was allocated to this grouping. This therefore confirms that commercial premises are the most vulnerable type of property to urban rainwater flooding.

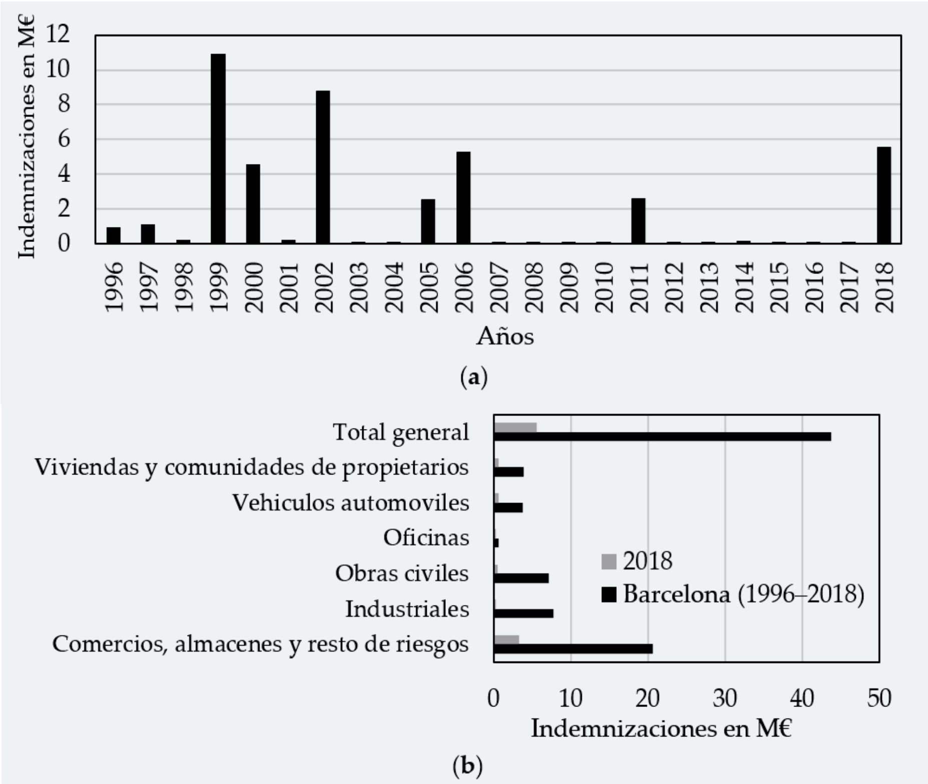


Figure 4. Compensation paid and provisioned by the CCS 31 July 2019 for loss due to pluvial floods in metropolitan Barcelona; a) Annual historical totals (1996 to 2018) and b) Historical totals (23 years) grouped into types of properties. Prices updated as of 2018.

Figure 5. Aftermath of pluvial floods in the city of Barcelona which occurred on a) 9 October and b) 15 November 2018.
Sources: a) https://www.elperiodico.com y b) https://www.telecinco.es.

This data highlights the significance of urban flooding from rainfalls and clearly shows a need for tools that help to estimate the damage that they can cause. Barcelona, which is demonstrably only affected by pluvial flooding, comes third in the ranking of Spanish municipalities hardest hit by floods, classification composed by both riverine and rainfall processes.

How is flood loss estimated in Barcelona?

The economic impact of pluvial floods can now be estimated for the city of Barcelona thanks to tools developed within the RESCCUE project. A loss appraisal model has been devised in collaboration with an insurance adjuster with extensive experience of floods. The construction of this model brings in the expertise accumulated from vast experience in estimating loss from this kind of hazard.

The role of the insurance adjuster in rain floods

The CCS covers so-called "extraordinary risks", which include natural hazards such as flooding that stem from, i.e. rainfalls where these risks are not expressly borne by the original insurer in the insured's policy. Its cover includes losses arising from direct property damage, those from business interruption, costs and losses from housing not being habitable, and personal injury.

When an extraordinary risk event occurs, such as the rain floods in Barcelona on 9 October and 15 November 2018 (Figure 5), the CCS sends out one or more adjusters who are experts in making an initial estimate of the extent of the damage caused. According to conversations with the CCS, these estimates, which are the product of the experience and knowledge of the effects of flooding gained by these professionals, are definitely reliable. Therefore developing tools and methodology that reflects the expertise of these professionals can be extremely valuable when it comes to flood damage assessment in Spain. In relation to this point, the United States Army Corps of Engineers (USACE) already based itself on the opinion of the expert to develop the depth-damage curves for the various states in the country (Gulf Engineers & Consultants [GEC], 2006).

The transfer of water from the streets into the inside of the property

Although flood damage curves are a key element in estimating damage caused, this calls for the depth of water which there might be in the property to be known (or conjectured). It often happens that the depths obtained from hydrodynamic models in the area (i.e. streets) surrounding a property are applied directly, but in the case of flooding from rain it is thought that the depths on the inside of a property are likely to be considerably shallower. On the other hand, in a rain-induced flood event water residence time is thought to be long enough for the levels in the street and within the property to level up. This is what the conceptual model developed (Figure 6) seeks to define to achieve an estimate of the depth indoors that should be used when applying the damage curves.

A key element which limits the depth that comes into contact with the access to the property (y_o, Figure 6) is the height differential at the entrance, which is different for each use. This is in fact a protective element for properties, the more so the higher the differential is. With commercial premises in general there is either no step at the entrance, or else it is very low (Figure 7), to facilitate customer access. A field study in metropolitan Barcelona has managed to obtain average readings for steps (height differentials) that can be associated with the various different kinds of properties being taken into account.

Thus the flood depth in the street, which is normally provided by a hydrodynamic model that takes into account the run-off and network overflows on the surface, is "reduced" by this height differential. The depth left after this reduction is the one which will cause water to enter the property.

The depth inside the property (y_{GF}, Figure 6) is expected to be lower than it is in the street, to a greater or lesser extent depending on the number and type of closable openings. This assumption is based on the fact that with rain floods the water residence time in the streets lasts for only very few hours, or even minutes (Chen et al., 2010).

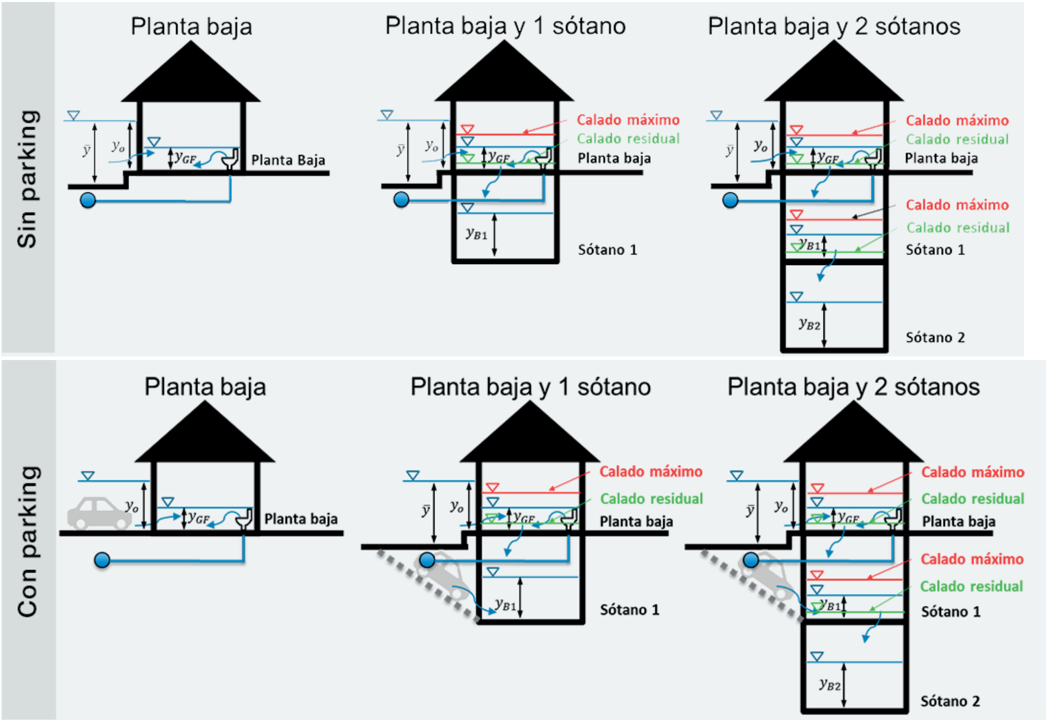


Figure 6. Conceptual model of the transfer of water-level from the streets into the inside of the property.

Figure 7. The entrance doors and almost non-existent steps of two commercial premises in metropolitan Barcelona.

This approach posits a model for the transfer of the depth of water in the street to that inside the property in urban zones which is depicted diagrammatically in Figure 6. This shows different building configurations: 1) only a ground floor, 2) a ground floor and a basement and 3) a ground floor and two basement levels. These three configurations are also considered with a carpark ramp, given that this allows more water to enter. With just a ground floor, the water depth can rise to the level in the street, yet the presence of basements means that a certain maximum depth is not surpassed because the water shifts down to lower levels afforded by the basement/s. A residual level is also accepted, which is that which will remain on the ground floor after the event concludes and is accumulated water that will not increase the depth on lower floors. The damage curves are therefore applied using the depths inside the property (y_{GF}, y_{B1}, y_{B2}, Figure 6) consistent with this approach.

Permeability of properties

Closable openings (doors and windows) are the places through which water moves from the streets into a property in the event of a flood. It is assumed that they are not left open in a flood situation and they can be watertight to a greater or a lesser degree, although it seems evident that the water depth inside properties will be greater than it is outside (Figure 8).

Figure 8. High-water marks following a flood event both inside (49 cm) and outside (110 cm) a property.

As has already been pointed out, the water residence time is a key factor in the ratio of the water depth outside to that inside a property, but in the case of urban rain floods this time is typically not long enough for the two water levels to equal each other. Thus a permeability ratio is proposed to illustrate the relationship between both depths (y_{GF}/y_o), that which can be expected within the property (y_{GF}) and that experienced in the streets (y_o).

There being no available data on flood depths in the streets where buildings stand for which their inside flood depth is known, the permeability ratio has been estimated according to the opinion of the expert flood loss adjuster. These permeability ratios have been initially estimated for several different types of closable openings, as well as drains and syphoning systems. A premise with closable openings just made of glass (sliding doors, for example) and without aluminium metalwork would allow the water in more easily than other premises with frames. These ratios are also expected to vary according to the depth in the streets, given that a greater depth means a longer water residence time. For this reason, they are presented as dependent functions of the street-depth and type of closable opening or drain. In this way, aggregation of curves for closable openings and sanitation systems has enabled a curve of water-tightness ratios to be established for the various kinds of properties taken into account in this study (Figure 9).

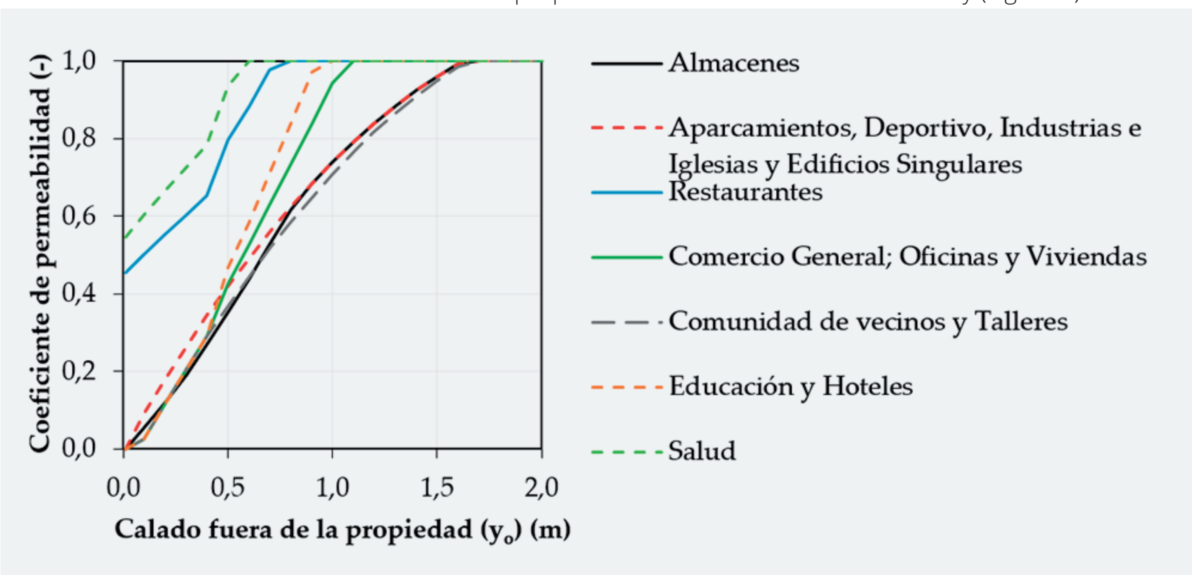


Figure 9. Water-tightness ratio curves for a) types of closable openings and b) kinds of properties.

Potentially floodable areas

On the other hand, the conceptual study presented makes sense for properties with a sufficiently small floorspace because if we consider extensive spaces, we can expect the water that comes into the property not to take up the whole area. In this respect we can draw a distinction between total floorspace and potentially floodable floorspace. Both of these amount to the same in the case of conventional commercial premises (Figure 10a), but they will differ substantially when the flooded street affects a hospital with a large floorspace (Figure 10b) or even a shopping centre, where the water is expected to occupy only a portion of it. Based on experience of performing adjustment for flooded properties, certain functions have been proposed to find out the potentially floodable floorspace as a function of the water-depth in the street (y_o) and overall floorspace (Figure 11).

Figure 10. Entrances to properties with a) small floorspaces (small businesses) and b) large floorspaces (hospital).

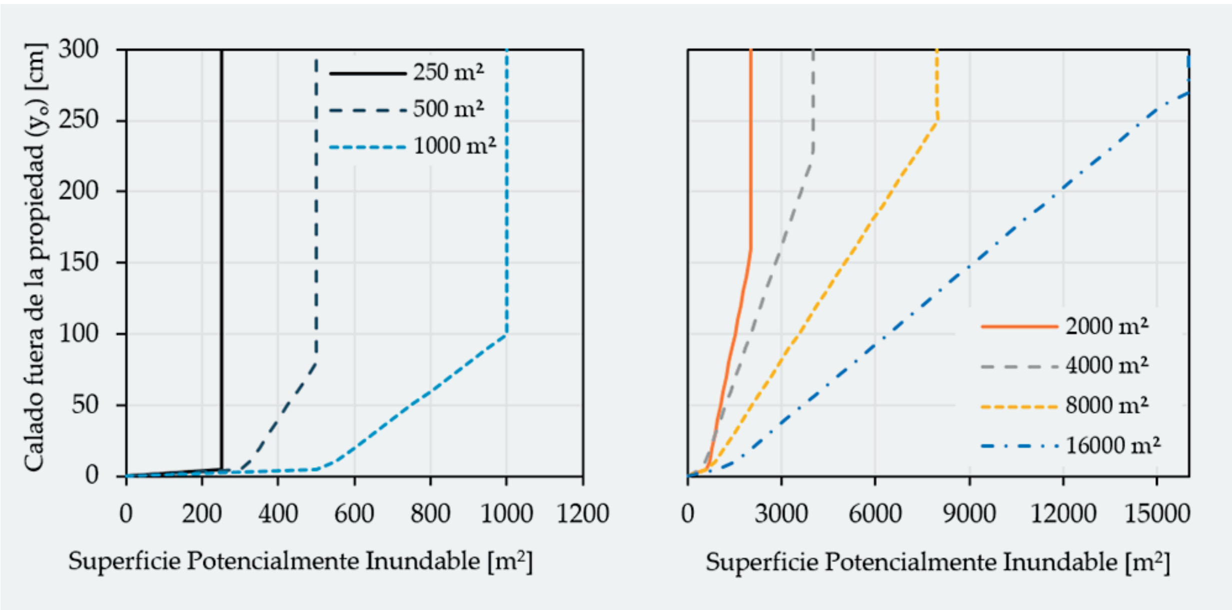


Figure 11. Potentially floodable floorspaces.

Developing damage curves for Barcelona

By way of a last, though essential, element depth-damage curves have been specifically designed for Barcelona. To construct them, a comprehensive analysis has been made of 378 records of flood-hit properties nationwide for which their loss adjustment value, the compensation paid out by CCS and the water-depth inside the property that caused the loss was known. The floods reviewed took place over 2012-2018 and affected Spanish cities with differing economic levels and located in the Mediterranean and Atlantic (Bay of Biscay) areas. These records reflect damage caused by pluvial floods in the Mediterranean zone and fluvial floods in the Atlantic zone. The former relate to damage caused by medium and low depths (up to 50 cm on the ground floor), whereas the latter prompted deep flooding (up to 100 cm) inside properties.

The final results from the depth-damage curves for Barcelona (Figure 12) were obtained after combining linear adjustments according to the relevant data but featuring input from the claims adjuster (semi-empirical curves) on those sections of the functions where there was a paucity of data or the correlation was weak (Martínez-Gomariz et al., 2020).

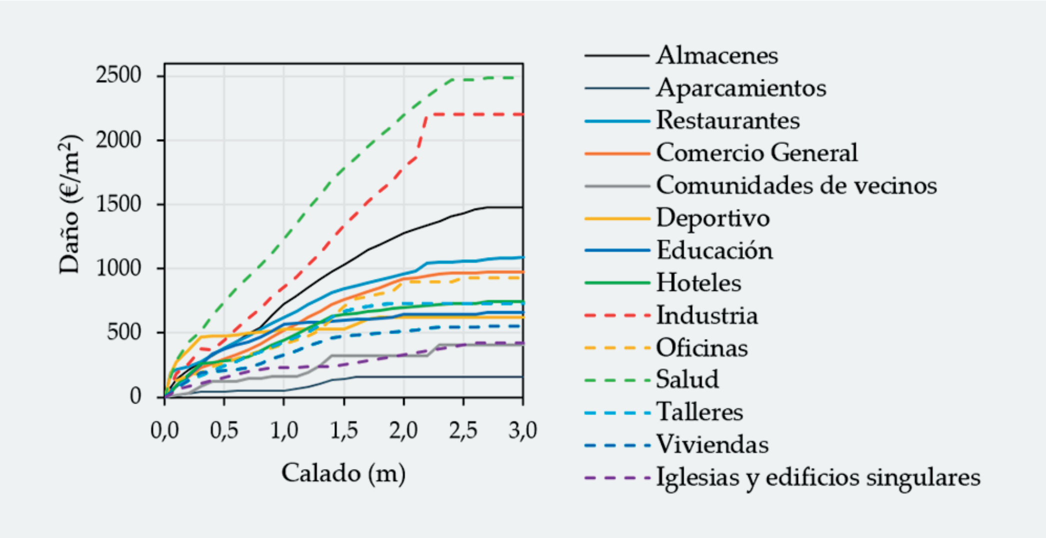


Figure 12. Semi-empirical depth-damage curves for metropolitan Barcelona.

Regional and temporal transfer of the damage curves

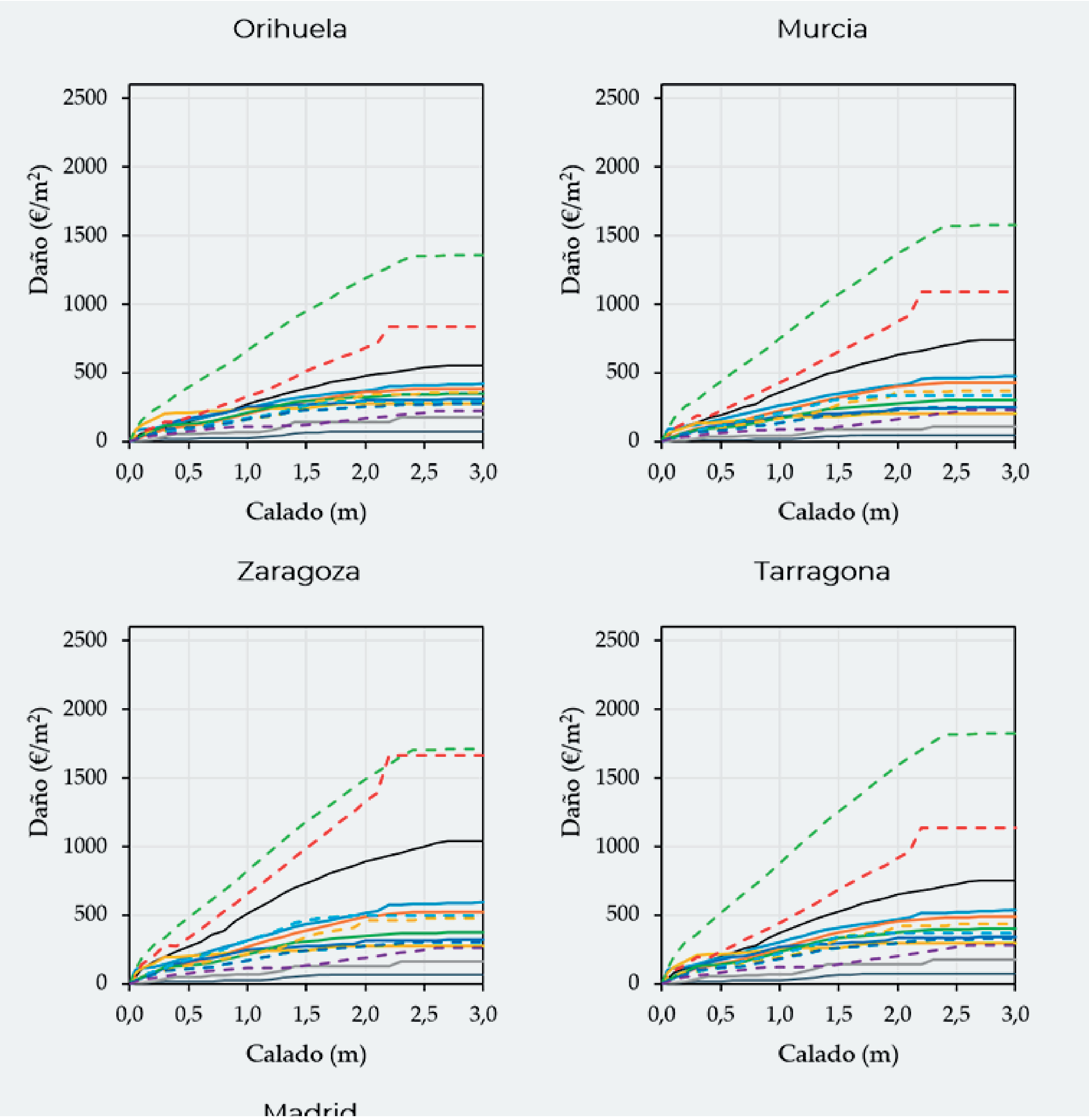
Using the semi-empirical depth-damage curves constructed for metropolitan Barcelona as part of the RESCCUE project as a starting point, we have gone one step further and **developed a methodology to transfer these curves onto other Spanish municipalities. This allows depth-damage curves to be used for flood loss appraisals nationwide by applying curves obtained via a common methodology.**

To transfer the Barcelona curves regionally to a large portion of the 8,131 Spanish municipalities, demographic , economic and geographic factors have been taken into consideration, since they have a bearing on the variability of prices for goods and services in the country (IBI Group, 2015). To do this we have obtained regional adjustment indices which show the proportionate price variation for a curve for Barcelona relative to a different Spanish municipality.

The different types of properties taken into account have been grouped into three broad sectors, namely commercial, industrial and residential, and others. We have assumed that the three property components (the building, furniture and furnishings, and stocks) show differing price variations. For example, we assume that the prices of buildings used for storage vary in the same way as a commercial building, but that on the other hand the remaining components (furniture, furnishings and stocks) exhibit price variability on a par with the industrial sector. After the indices have been obtained for each component, the component curves for Barcelona are adapted to find the curves for each component in the municipality for which depth-damage curves are sought. Aggregation of the component curves gives us the municipality's depth-damage curve for the types of properties taken into account. Figure 12 shows the depth-damage curves constructed for some of the municipalities worst hit by flooding in Spain in recent years.

Temporal transfer of curves is also useful for evaluating future potential flood damage. Temporality indices constructed using the economic scenarios forecast by the OECD up to 2060 (OECD, 2020) can be applied to the depth-damage curves constructed for a municipality.

Details of this study can be found in the article "Depth Damage Curves for Spanish Urban Areas" (Martínez-Gomariz et al., 2020), which was published in the magazine Sustainability.



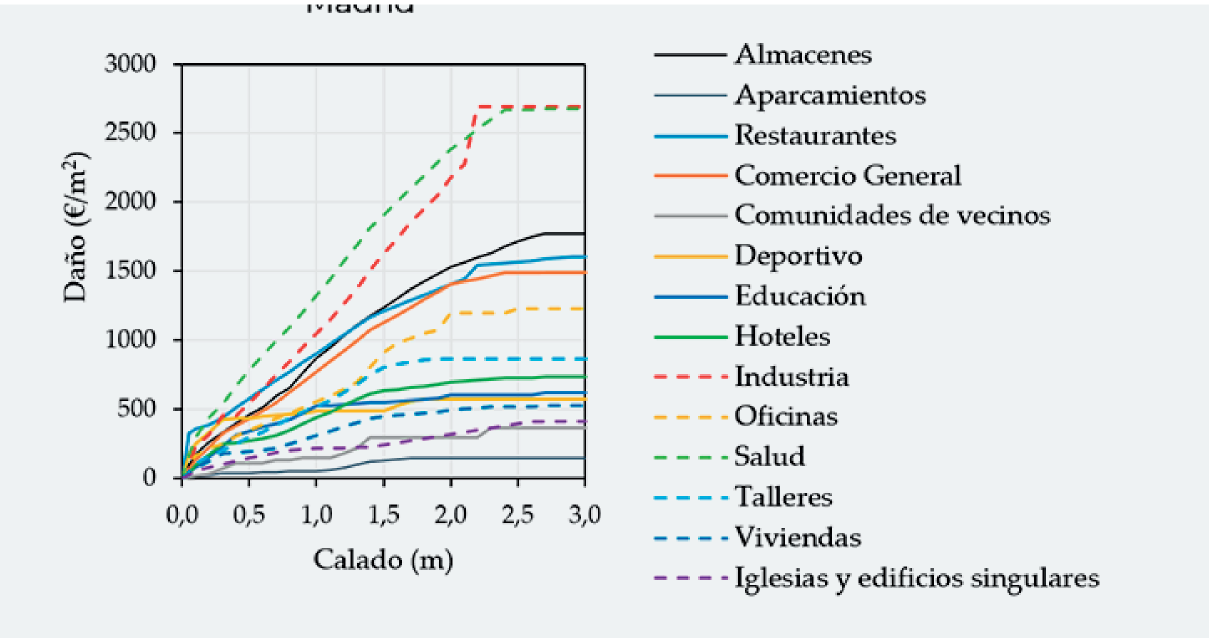


Figure 13. Depth-damage curves for some Spanish cities.

Conclusions

Using depth-damage curves is globally accepted, even while recognising the significance of factors not given consideration, such as water velocity or floodwater residence time. A large number of damage models are based on the depth-damage relationship. One of the biggest limitations of these curves thus far is their regional nature. This means that they are only valid for the place for which they have been constructed and, therefore, cannot be used appropriately elsewhere. Moreover, the need to continually bring prices up to date over time may also be viewed as a drawback when they are absolute curves (€). Even so, when they are relative depth-damage curves (%) there is greater consensus over their usefulness, since their shape remains unaltered over time. The shape of these curves is particularly dependent on the styles and types of construction employed in different regions, which could even be held to be reasonably uniform up to national level.

Barcelona is one of the case studies in the EU's RESCCUE project and is a city for which there has been thorough analysis of its resilience to climate effects. Of those it potentially faces, special attention has been paid to rain floods, which happen with increasing frequency every year. Among the different risks studied, an assessment of potential property damage has been made. To this end a detailed model has been developed that reflects the experience acquired by an expert flood claims adjuster. Due to the lack of depth-damage curves for Barcelona, specific curves have been constructed for the city based on genuine flood records and with the benefit of input of the knowledge built up in the course of adjustment work. These curves cover different uses of properties that are characteristic of highly-developed areas, such as Barcelona.

Furthermore, to extend development of depth-damage curves to the various Spanish municipalities we propose methodology that uses regional indices based on several demographic, economic and geographic indicators. To transfer the curves to future years, we propose a temporal index that allows taking curves up to the year 2060 in line with the economic forecasting which the OECD has estimated.

Both the conceptual model and the curves developed are tools that can be applied nationwide and therefore the results of damage assessment between different municipalities in Spain can become comparable. This work helps toward improving cost/benefit studies, their use being particularly important for pluvial floods, although it is also applicable to fluvial floods. Future revisions of Flood Risk Management Plans (Directive 2007/60/EC and Royal Decree 903/2010) will also pay attention to pluvial floods and the risks that stem from them, since there are now tools available to conduct studies of this type.

The insurance industry will also benefit from a damage assessment model that would allow it to estimate the order of magnitude of compensation pay-outs to be satisfied in the immediate aftermath of a flood, as well as to keep track of quality and fraud.

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Natural assurance schemes: moving earlier in the risk management cycle with nature based solutions and strategies

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Introduction

In Greek mythology, the Naiads (Ναϊαδες) are the spirits of small brooks, fountains, wells, springs, and other freshwater bodies. Different to the river gods, the naiads were smaller, more adaptable in different forms. The NAIAD project presented in this article takes inspiration from this freshwater ancient wisdom to look at disasters. Particularly, considering the prevention and reduction part of the disaster risk management cycle by looking at nature, not just as part of the problem but as part of the solution.

The ancient Greeks thought of the world's waters as all one system, which percolated in from the sea in deep cavernous spaces within the earth, to the sea. This systemic view on risks is very much at the heart of NAIAD. The approach is also focused on this versatility afforded by nature and the interest in understanding the protective role of nature-based solutions (NBS) in buffering risks posed by natural hazards through the development of natural assurance schemes.

Flood events have huge impacts worldwide. In Europe, numerous examples can be found from the past decade, that cause extensive damages (e.g., cloudburst in Copenhagen, the Elbe floods in 2002, 2013, Danube floods in 2006, Alpes Maritimes floods in 2015, Lez floods in 2014, Seine floods in 2016 and 2018, etc.). Around 90 % of natural hazards are water-related and these are likely to become more frequent and more severe due to climate change. For example, climate change is projected to increase damages up to 50 % by 2050 in France (Moncoulon et al.

The main objective of the EU funded NAIAD project is to develop a better conceptual framing and understanding on the insurance and assurance value of nature to help address and prevent damages from natural hazards by bringing nature into the equation not just as a problem but as a solution. NAIAD is a project funded by the European Commission under the program Horizon 2020 running over 3 and a half years (2017-2020) with a budget of 5 million euros. This short article will present the main results from developing this conceptual frame and the operationalisation of the assurance value of ecosystems in disaster risk management, putting a special emphasis on prevention and avoided damages through nature investments.

2018). The *Caisse Centrale de Réassurance* (CCR) has estimated that mean annual insured of flood hazards will be up to 38 %, respectively 50 % related to runoff hazard and 34 % to river flooding.

Climate change is already resulting in rising levels of risk posed by natural disasters and the related costs these create (Lawrynuik 2019). The total reported losses caused by natural disasters over the period 1980-2014 reached approximatively 453 billion euros in Europe, with only 45 % of these economic losses insured (EEA, 2019). Therefore the (re)insurance industry is a critical actor to engage and to understand its current and potential contributions to the assessment of what we have called Natural Assurance Schemes (NAS). The insurance sector has the opportunity to play different roles to engage loss prevention through NBS (Marchal et al. 2019). The use of catastrophe models developed by or for (re)insurance companies are tailored to assess the quantification of the avoided damage provided by preventive measures. It could be performed in addition of co-benefits assessment supported by both research institutions and specialist organisations with knowledge on the role of green infrastructure in delivering resilience dividends.

1. The main aim and strategic goals

The main objective of the EU funded NAIAD project[1] is to develop a better conceptual framing and understanding on the insurance and assurance value of nature to help address and prevent damages from natural hazards by bringing nature into the equation not just as a problem but as a solution. NAIAD is a project funded by the European Commission under the program Horizon 2020 running over 3 and a half years (2017-2020) with a budget of 5 million euros. This short article will present the main results from developing this conceptual frame and the operationalisation of the assurance value of ecosystems in disaster risk management, putting a special emphasis on prevention and avoided damages through nature investments.

The project is coordinated by the Duero River Basin Authority. It has brought together a consortium of 23 partners from 11 European countries including 3 universities and education research institutes, 8 research centres, 4 small/medium size enterprises, 3 public bodies with competences in applied research, 2 public bodies with key competencies in management (the city of Copenhagen and the Duero Basin Authority), 2 NGOs, and the French public reinsurance company CCR.

The project´s purpose is fully aligned with the upcoming draft EU adaptation strategy "Adapting to climate change"[2] and EU Taxonomy on Sustainable finance including 68 activities on climate change adaptation[3] published in March 2020, contributing to make our societies (and our activities) more climate resilient. NAIAD starts from the assumption that healthy and fully functioning ecosystems can significantly contribute to mitigate extreme water risks and increase the resilience of society in a context of climate change.

To demonstrate the role ecosystems can play in reducing water related risks (e.g. frequent and extreme events) the project has developed what we have termed "Natural Assurance Schemes" (NAS). The project included 9 demonstration sites across Europe spanning different scales: from large scale like the Thames basin (UK), the Lower Danube (Rumania) or the Medina aquifer (Spain), to middle scale like the Lez, Brague (France) and Glinščica (Slovenia) catchments, to city scale of Copenhagen (Denmark), Rotterdam (Netherlands) and Lodz (Poland). These sites face different hazards, the majority focused on floods both pluvial and fluvial (Danube, Glinščica, Lez and Brague), whereas the Medina aquifer in Spain focused on droughts. These different sizes range from the smallest, a neighbourhood in the city of Rotterdam, to the largest one, the lower Danube, with a stretch 250 kilometres long. These cover urban,

(1) www.naiad2020.eu
(2) An open public consultation is open until 20 August to gather stakeholder views and feedback for the design of the new strategy. A blueprint accompanies the consultation in order to provide context, indicate possible directions of development and stimulate the debate.
(3) https://ec.europa.eu/knowledge4policy/publication/sustainable-finance-teg-final-report-eu-taxonomy_en

peri-urban and rural environments, including cities, basins and aquifers as units of analysis. Most importantly, in relation to the design of natural assurance schemes, our demos also cover cases that started from scratch like in Romania or Slovenia, to cases that were fully implemented and where attention was given, instead to developing robust monitoring and evaluation frameworks, to monitor the effectiveness of measures taken for e.g. natural flood management in the Lower Thames.

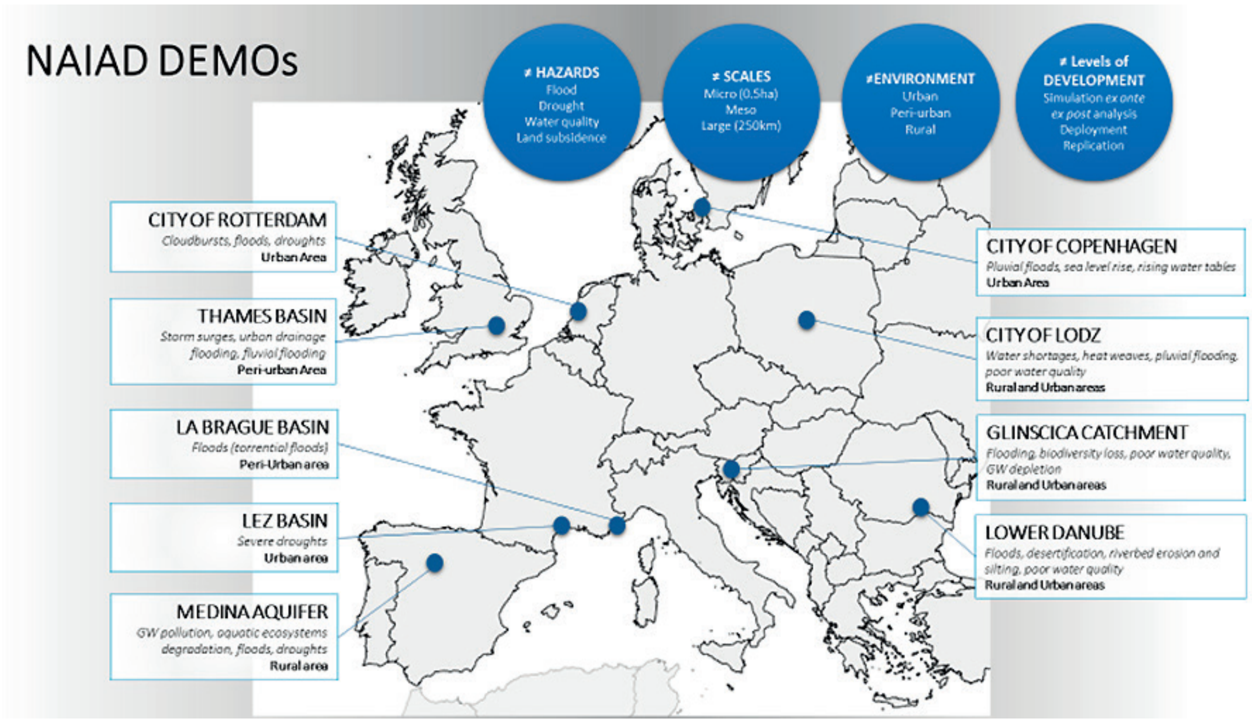

Figure 1: NAIAD Demo location and main focus.

With this, the project aims to propose new concepts and approaches to enlarge the portfolio of available solutions. Conventional infrastructural measures are expensive - the investment needed in water infrastructure over the next fifteen years has been estimated at 22 trillion dollars, which is more than half of the total expected infrastructure investment demand (USD 41 trillion) (WEF, 2019).

To achieve the central aim of demonstrating the assurance value of ecosystems, three strategic goals were identified:

- To develop biophysical, social, and economic assessment tools and methods to provide relevant decision and planning support frameworks for identifying, co-designing and simulating NBS strategies for specific locations.
- Testing these tools and methods at the 9 demonstration sites/real environments, providing evidence on the value of ecosystems for DRR and Ecosystem based adaptation.
- Policy uptake and exploitation of the results of the project, by engaging different decision makers and policy makers at different levels. This will help to validate the results and identify next steps towards further implementation, as well as knowledge gaps that merit further research and development.

The paper -after a brief discussion on the main conceptual frame- will now present in sequence over the coming sections the results for these three strategic goals.

2. The conceptual frame: natural assurance schemes for the uptake of NBS for ecoDRR and ecosystem-based adaptation

There is a realisation on the relevance to move earlier into the risk management cycle while helping to adapt to climate change and Disaster Risk Reduction (DRR). Here the role of mainstreaming and normalizing NBS as an alternative or complement to conventional grey solutions to prevent or reduce risks. Thus, increase resilience and response capacity to water related hazards.

The interest in Nature-based Solutions (NBS) has significantly increased over recent years. The European Commission (2015) defines nature-based solutions as solutions that are inspired and supported by nature, which are cost-effective, and simultaneously provide environmental, social and economic benefits and help build resilience. NAIAD focused particularly on how NBS can help society become better prepared and more resilient to natural hazards, looking at the value from prevention in terms of avoided damages and other benefits, what we have termed "the assurance value". NBS offer different functions, from conserving or rehabilitating natural ecosystems, the enhancement or creation of natural processes in modified or artificial ecosystems, and can be applied from the micro- (e.g. a small wetland) or macro- (e.g. flood plain restoration) scales (WWAP/UN-Water, 2018).

We have made a conceptual difference starting from the fact that the insurance value can have several interpretations or components depending on the value dimension considered, and more specifically who/what is insured: the ecosystem or the humans? and the risk considered. Thus the difference between nature insurance, when e.g. a mangrove is itself insured for the protective value as a financial product for risk transfer versus the "assurance value of nature", i.e. the protective functions from nature itself, whether insured or not[4]. Theoretical aspects of the insurance value of ecosystems have already been covered in the literature (Pascual et al., 2010; Baümgartner & Strunz, 2014), yet there is a lack of operational methods building on these theories that enable cities or basins to assess strategies including NBS against grey strategies or status quo.

A series of the tools and method has been developed and will be briefly presented in this paper[5]. These schemes are designed to capture the natural Assurance Value in the reduction of risks that natural systems can secure (Denjean et al., 2018, Marchal et al. 2019[6]). This includes the full range of economic, financial, regulatory, institutional and stakeholder mechanisms that regulate a sustainable and equitable flow of primary and co-benefits between NBS and society. What has developed is a structured, modular approach with the development of (1) methodologies to assess and value NBS biophysically, socially and economically, (2) the notion of risk perception and (3) experiences with implementation of NBS in the NAIAD case studies have furthered this definition of NAS to operationalize all elements of the enabling environment.

3. Biophysical, social, and economic assessment tools and methods

The starting point for all of our demos was the biophysical assessment of their risks. Several tools and methods have been developed that can do this and that are suitable for the different scales.

3.1. Biophysical tools and methods at different scales- the Eco:Actuary tool kit and the FEV tool

For example, the Eco:Actuary Toolkit was developed for the larger scale demos. This toolkit consists of three elements. First, the Eco:Actuary Decision Support Tool is a global spatial catastrophe model which maps flood risk and exposure

(4) Please check our infograms on the different natural hazard insurance business models at http://naiad2020.eu/wp-content/uploads/2019/03/Newsletter05.pdf
(5) For more details into these tools and methods please visit http://naiad2020.eu/media-center/resources/
(6) http://naiad2020.eu/wp-content/uploads/2018/10/Newsletter02.pdf

under current climate and Intergovernmental Panel on Climate Change scenarios as well as loss mitigation and avoided losses by use of natural flood management (NFI interventions. Second, the //Smart:River Freestations (see F 2) which links real time low cost DIY IoT-linked monitori (FreeStations) to understand NFM contribution to flood ri reduction. Finally the Eco:Actuary Investment Planner, simple, online spreadsheet based tool that allows assessme of the scale and approximate cost of different types interventions required to achieve a specified flood reductio goal. The relevance to the insurance industry is that natur catastrophe models are commonly used tools in the insuran industry. They help insurers assess the severity of risk and th set appropriate insurance premiums. The Eco:Actuary Tool includes a catastrophe model with a range of scenario optio to explore the effects of climate change and flood mitigatio options such as changes to land use, land manageme practices and natural flood management interventions.

Figure 2: Image of a //Smart:River FreeStation: using IoT for flood prevention.

In some countries the insurance industry and nation government are closely aligned with increased awareness in the insurance industry to help reduce flood risk. That is how insurance and mitigation interact. By investing in mitigation interventions, insurance companies could save on compensation in the long term. //Smart uses networks of low cost IoT connected water level loggers can be used for (a) understanding the effectiveness of flood mitigation measures, (b) monitoring peak flows during flood events as either an early warning system or a real time data feed for the development of parametric insurance, in which pay-out is made with a loss adjuster i.e. on the basis of flood depth.

Other tools and methods suitable for smaller scales were also developed like the «Flood-Excess-Volume» method and tool (FEV), which provides a rapid assessment on the cost-efficacy of flood-mitigation strategies: In order to optimise the tailoring of generic flood-mitigation strategies to specific river-catchment scenarios, an algorithmic protocol, or «tool», is required that can assess a wide range of measures in a clear, quantifiable, educational and user-friendly fashion that is accessible to a wide audience. Through a collaboration between the University of Leeds, UK, and the EU-funded NAIAD project, precisely such a tool has been developed and tested on data accrued from real flood events occurring in the UK, France and Slovenia (for more details please see: Bokhove et al., 2019, 2020) (for further details see the insert about the Flood-Excess-Volume tool).

THE “FLOOD-EXCESS-VOLUME” TOOL

By Piton, G., Tacnet, J.M., Bohove, O. y Kelmanson, L.A.

Optimally, the tool should overcome two main obstacles. First, it should identify and utilise indicators of flood severity that are quantifiable, easy to understand and to measure; this makes the tool objective, transparent to scrutiny and user-friendly; crucially, it also admits repeatability and flexibility. Second, it should be capable of rapidly verifying whether a given ensemble of protection measures are sufficient to mitigate against an *a priori*-specified degree of flood severity.

The input data required by the tool are the project-flood hydrograph (i.e. the water-discharge time series), the water stage-discharge curve (i.e. the channel capacity) and the threshold level (i.e. the discharge above which severe flooding occurs).Using this information, the tool first computes the Flood-Excess-Volume (FEV), i.e., the amount of water that cannot be contained by existing flood defences for a given flood (see Figure Ia). Second, it computes the size of a virtual lake, 2m deep and square in shape, that could retain the computed FEV (see Figure Ib). This visualisation –of a virtual square lake of human-scale depth– helps stakeholders to assimilate in a meaningful way the excess of water that must be contained to offer flood protection. Importantly, it is to be contrasted with the somewhat less-intuitive visualisation of the actual catchment topography. The simplified visualisation deliberately allows, and hence empowers, a wide and non-expert audience to comprehend the magnitude of the amount of water that needs to be contained to mitigate against flooding.

The last step is to split the lake into constituent components, each of which is associated with a specific flood-protection measure (see Figure Ic) such as restored wetlands, leaky dams, flood-plain reconnection, flood-retention dams and giving-room-to-the-river, etc.

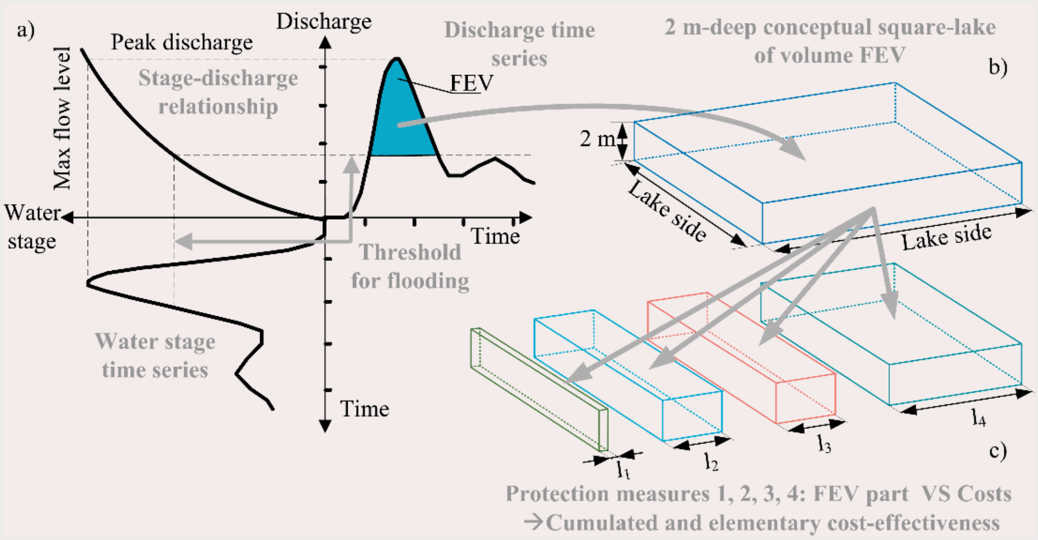

Figure I: The three stages of a FEV analysis.
(a) Three-panel graph highlighting FEV: (bottom-left) river-level time series, (top-left) stage-discharge relationship and (top-right) discharge data, in which FEV is the blue area, i.e., the peak volume above a chosen threshold discharge. (b) FEV square-lake representation as a 2m-deep square lake facilitates visualisation of FEV magnitude, or severity. (c) FEV-effectiveness assessment computed for each measure, of various colour, as equivalent FEV fraction (adapted from Bokhove et al., 2019).

3.2. Participatory modelling- turning barriers into opportunities for collaboration and collective action

The second type of method focused on the social assessment based on a participatory modelling tool for NBS co-design. The method aimed at handling ambiguity in risk perception though inclusive and equitable engagement of the different stakeholders. The tool was mainly based on system thinking approach. That is, the developed model aimed at defining and analyzing the complex and non-linear causal connections, affecting the behavior of the system to be managed. The tool is based on the sequential implementation of different phases: i) individual risk perception elicitation and analysis; ii) development of the System Thinking-based model; iii) detection of the main barriers to NBS co-design and implementation; iv) trade-off analysis and conflicts identification. Specifically, the analysis carried out in phases i) and iii) allowed NAIAD to bring stakeholders and decision-makers in a participatory process which main scope is to co-design effective interventions for reducing the water-related risks and producing the expected co-benefits. The methods implemented in phase iv) were meant to enhance the equity of the NBS implementation process. Stakeholders were capable of recognizing their contributions in the model, developing a sense of ownership in the obtained results. The effectiveness of this approach to also develop indicators which are placed specific has now been developed for the Glinščica catchment (Santoro et al., 2019; Pagano et al. 2019), the Lower Danube (Giordano et al., 2020) and the Medina Aquifer (Giordano et al, 2020).

The Participatory Modelling approach adopted in many NAIAD demo sites contributed to engage different stakeholders in a NAS design process that was inclusive, legitimate and cooperative. This, in turn, contributes to enhance the NBS social acceptance. Specifically, the adopted method and accompanying modelling tool contributed to the inclusiveness and legitimacy of the participatory process by giving voice to the different point of views concerning the management of water-related risks. The tool aimed at enhancing the potential richness, diversity, and complexity of the collected knowledge, rather than searching consensus among participants. To this aim, the tool was based on individual cognitive models, representing the individual perceptions of the water-related risks to be dealt with, the main impacts at local level, and the main social issues that need to be addressed. The integration of the knowledge of the different stakeholders and the scientific knowledge allowed developing a model that was perceived as legitimate by the participants. They could recognize their contributions in the model, developing a sense of ownership toward it and the obtained results.

Concerning the cooperation issue, two key benefits were produced during the participatory modelling process. Firstly, the stakeholders' engagement for the model development contributed to build relationships among the stakeholders, and between them, the scientists, and the decision-makers. Secondly, the participatory modelling tool allowed unravelling the complex network of interactions taking place between the decision-actors involved in the NBS design and implementation. The results obtained in different demo sites showed that ineffective interaction networks represent a barrier to NBS implementation. Therefore, measures and actions are needed to enhance the cooperation among different institutional and non-institutional actors to effectively implement NBS.

Thus in parallel to the physical and socioeconomic evaluation carried out by the technical partners of the project, meetings were organized at the local level in the 9 demonstration sites. During these meetings, in addition to informing local stakeholders about the project's objectives, public participation sessions were held where the participants (project stakeholders) took part in the achievement of various NAIAD tasks in collaboration with the technical partners (see Fig 3).

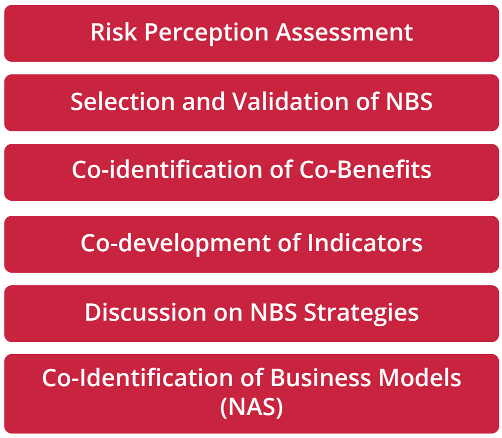

Figure 3: Co-design process.

3.3. Integrated cost-benefit analysis of Nature based strategies

The economic assessment framework, which is one of the pivotal elements in the development of natural assurance schemes, was developed with accompanying detailed guidelines aiming to compare the main costs and benefits generated by NBS for water related risks. We particularly developed methods for the monetary assessment of different costs and benefits:

- Costs of implementation: those that are necessary for the implementation and maintenance of the NBS included in the NBS strategies.

- Opportunity costs: related to the loss of benefits of areas that are taken out of production, or land that is used for NBS and that cannot be used for other profitable purposes such as the construction of building. These are the indirect costs of the NBS strategies.
- Avoided damages: the damages avoided due to the reduction of water risks generated by NBS strategies. Avoided costs are the primary benefit generated by NBS strategies aiming at reducing water risks.
- Co-benefits: the additional environmental, economic, and social benefits generated by NBS. utilizados para albergar SBN y que no pueden utilizarse para otros fines económicos como la edificación. Son costes indirectos de las estrategias de SBN.

The economic assessment subsequently compares these costs and benefits over the life-time of alternative projects, grey, hybrid and NBS, with a Cost-Benefit Analysis. Our results reveal that the cost of implementation of NBS is lower than the cost of grey solutions for the same level of reduction of water risks. This reinforces claims about the cost-effectiveness advantage of NBS and would urge decision makers to consider more systematically these solutions to address water risks. However, the economic benefits related to the reduction of flood damages are not sufficient to fully cover investment and maintenance costs. This problem may be a challenge to have these solutions funded by sectorial financing mechanisms focused on the reduction of water risks. Instead more comprehensive projects would tap into all the benefits.

Co-benefits (reduced air pollution, reduction of heat in cities, improved landscape, climate change mitigation…) and these represent the largest share of the value generated by NBS strategies. The co-benefits are needed for these solutions to be economically beneficial, while initially designed to reduce water risks. This multiplicity of benefits therefore requires project developers to look for and blend multiple sources of funding and financing. Enabling policies for NBS development would therefore require facilitating this process.

For the case of avoided damages, we relied on the expertise of CCR with their CAT Model. Modelling of overflow and runoff hazards is performed in the first unit; insured contracts geolocalized at the address level with information on the type of risk and insured value are available in the second unit; the last unit merges hazard to vulnerability with damage curves linking water height/water flow to destruction rate. Finally, it is possible to estimate the insured losses as consequences of a natural disaster (see the insert about CAT Models).

LOSS DAMAGE ASSESSMENT AND USE OF CAT MODELS: LOSS PREVENTION THROUGH NBS

By Marchal, R. and Moncoulon, D.

The (re)insurance industry has an increased interest in assessing the effectiveness of preventive measures by using its expertise in modelling hazard and in loss damage assessment. Such a tool has been used and replicated in France within a collaboration between the French partners involved in the EU-funded NAIAD project.

Interest in understanding the protective role of nature-based solutions (NBS) in buffering risks posed by natural hazards is growing within the (re)insurance industry. The sector has different roles to engage loss prevention through NBS (Marchal et al. 2019). The use of catastrophe models developed by (re)insurance companies is tailored to assess the quantification of the avoided damage provided by preventive measures.

Caisse Centrale de Réassurance (CCR) French public reinsurance industry, along with French researchers from INRAE, BRGM and University of Nice implemented this framework during the NAIAD project, in order to increase knowledge on the role of NBS in loss prevention and support local decision-making process. The following paragraphs will focus on the methodology applied by CCR for modelling flood events by using its CAT model for assessing hazards and the avoided damage. The loss projections in a context of climate change has also been studied, based on a global climatic model linked with flood impact model (Moncoulon et al. 2018).

CCR is modelling some direct and tangible damage and hazards (floods, earthquakes, marine submersions etc.) within the frame of the French Natural Catastrophes Compensation Scheme. A CAT model is composed of a hazard, vulnerability, and damage units (Figure II). Modelling of overflow and runoff hazards is performed in the first unit; insured contracts geolocalized at the address level with information on the type of risk and insured value are available in the second unit; the last unit merges hazard to vulnerability with damage curves linking water height/water flow to destruction rate. Finally, it is possible to estimate the insured losses as consequences of a naturel disaster.

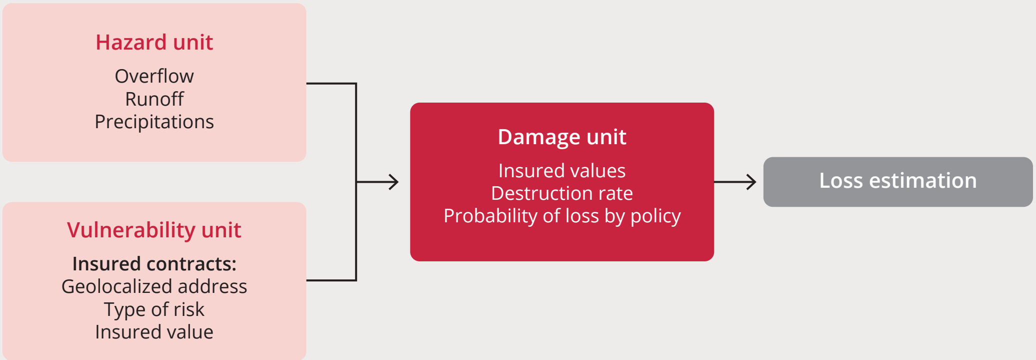

Figure II: Catastrophe model structure.

The first step in a Cat model is to run the hazard unit. The CCR overflow/runoff model is a 2-D distributed model at 25m-resolution calibrated at the watershed scale for the entire French territory (Moncoulon et al. 2014).

The model has been adapted to the French demonstrations sites at catchment scales and to the selected past flood events: a) Collecting local information especially on the land-use occupation; b) Adapting the digital terrain model slopes calculation to be tuned to take into account water height on each mesh in order to sprawls water along short watercourses. At catchment scale calculation duration are shorten than at the country scale.

Then, flood hazard modelling is validated by comparison with the local information collected during the disaster events (i.e., flood marks, flood extent). In parallel, information on the insured damage (claims) for the selected events are extracted from the insurance portfolio at the street center or address resolution level. The calibration of insured damage functions relies on the hazard and vulnerability units' outputs. Often there is no damage curves specifically representing runoff or overflow damages in the studied area. Such curves are used to obtain costs and probability of losses.

The damage unit is based on the damage function which is the correlation between hazard characteristics and observed damages. The observed damages are defined by the destruction rate (DR). The DR is obtained by dividing the number of claims by the insured value.

$$DR = \frac{Amount\ of\ claims}{Insured\ value}$$

The damage function is then: 〖DR〗 r= f(m^3/s o m). The damage function could be fitted for different types of risks such as residential homeowners, commercial, industrial, or agricultural businesses.

Two curves are then calibrated: damage rate curve which is the average destruction rate per water flow/water height class, integrating the probability of losses; damage curve which is the average destruction rate per water flow/water height class with claims only.

The curves validation is done by comparing the real costs to the simulated ones at the flood event scale on the studied area. The damage functions calibrated on the studied disaster events and at the catchment scales are then used to estimate the avoided damage of NBS. Within the damage unit, a reduction rate of hazard intensity has been applied on the model to estimate the avoided damage. These hazard reduction scenarios have been chosen to estimate the avoided damages on a 10 to 50 % reduction range. The impact of NBS on the hazard reduction is depending on the NBS nature and flood event intensity. It will be estimated by experts on the hydrologic modelling within the project and afterwards.

An x % of hazard reduction provides an estimate of avoided damage in euros. For example, on the Lez catchment, based on the 2014 flood Cevenol events for residential homeowners, a reduction of 50 % of runoff hazard will reduce the damage to ~1.9 €M or by 40.45 %.

These damage functions can also be integrated to assess the insured losses on probabilistic hazard at current and future climate. The annual average insured losses in the catchment are based on the stochastic simulation of 400 years of climatic hourly rainfall from ARPEGE-Climat at current and 2050 conditions (Moncoulon et al. 2018). It provides an overview of the future amount of damage per return periods and an estimate of the increased losses. Following this step, it is possible to calculate the requisite percentage of hazard reduction to reduce the effect of climate change to the current business-as-usual losses. For example, on the Lez catchment, the hazard has to be reduced by 35 % using NBS to limit the effect of climate change to the current losses.

4. Knowledge integration: adaptive planning, new business models and innovative sustainable financing

The knowledge obtained in each demo case resulting from the biophysical, social and economic analysis is integrated into a global framework that can be applied in environments with different technical, biophysical, social and economic challenges. To facilitate the integration and use of the multidisciplinary knowledge, support methodologies have been designed for decision-making.

A series of additional methods and tools were created to integrate the different elements in the assessment like the development of a stakeholder engagement protocol that supported the whole process of problem identification, potential solutions and favoured strategy (see Annex 1), which translated into a strong process of co-design with local stakeholders. This was then linked to the adaptive planning cycle and the use of a specific natural assurance business canvas to identify potential revenue flows and the financing framework on how to fund these NAS schemes focused on identifying finance options available (particularly around blended finance, impact investment and performance based contracts). We now explain each of the integrative methods in more detail.

4.1. The Adaptive planning cycle

First, through its strong framing under the adaptive planning as introduced by Basco et al. (2020) and analyzed and discussed by van Cauwenbergh et al. (2020), adaptive planning is a structured, iterative process of robust yet flexible decision making in the face of uncertainty, with the aim to manage uncertainty over time through system monitoring and learning from what is experienced, as the future unfolds. Using some of the models developed specifically for many of our case studies, it is possible to potentially develop Dynamic Adaptive Policy Pathways (DAPP), which is an iterative policy analysis process for adaptive planning that allows adjusting future action when events, that are presently unknown, unfold in the future. The DAPP approach combines "Adaptive Policymaking" with "Adaptation Pathways", and the developed plans include a strategic vision of the future, commit to short-term actions, and establish a framework to guide future actions. This was not implemented in our case studies, but it could be integrated into the current frame.

4.2. The Natural assurance Business Canvas

Second, through the natural assessment business canvas that is explained in Mayor et al. (2020). A business model is a conceptual tool containing a set of concepts and their relationship to each other, to fully develop the value proposition of a specific product or service. It allows for a simplified description and representation of what value is provided to customers, how this is done and with which funding sources and its financial consequences (Ostenwalder et al., 2010). The NAS Canvas is different on two accounts; first, because it is structured based on a logic of supply and demand of ecosystem services, and because it is based on a pluralistic understanding of value (Sanders et al, 2016) and relational values (Mouraca, B. & Himes, 2018) which are now part of the IPBES Framework and defined as "… imbedded in desirable relationships (sought after), included those between nature and people" (Diaz et al. 2016). Therefore the Natural assurance canvas captures not just the fully private values, but also the collective and public values, preparing the ground therefore for the collective alignment of a number of interested parties and their collective benefits, and willingness to pay for different services provided by multifunctional solutions like nature based strategies that deliver, often simultaneously, a bundle of services (collective benefits), i.e. the various benefits that can be provided by a NBS simultaneously over a certain period. (Jiang et al. (2016).

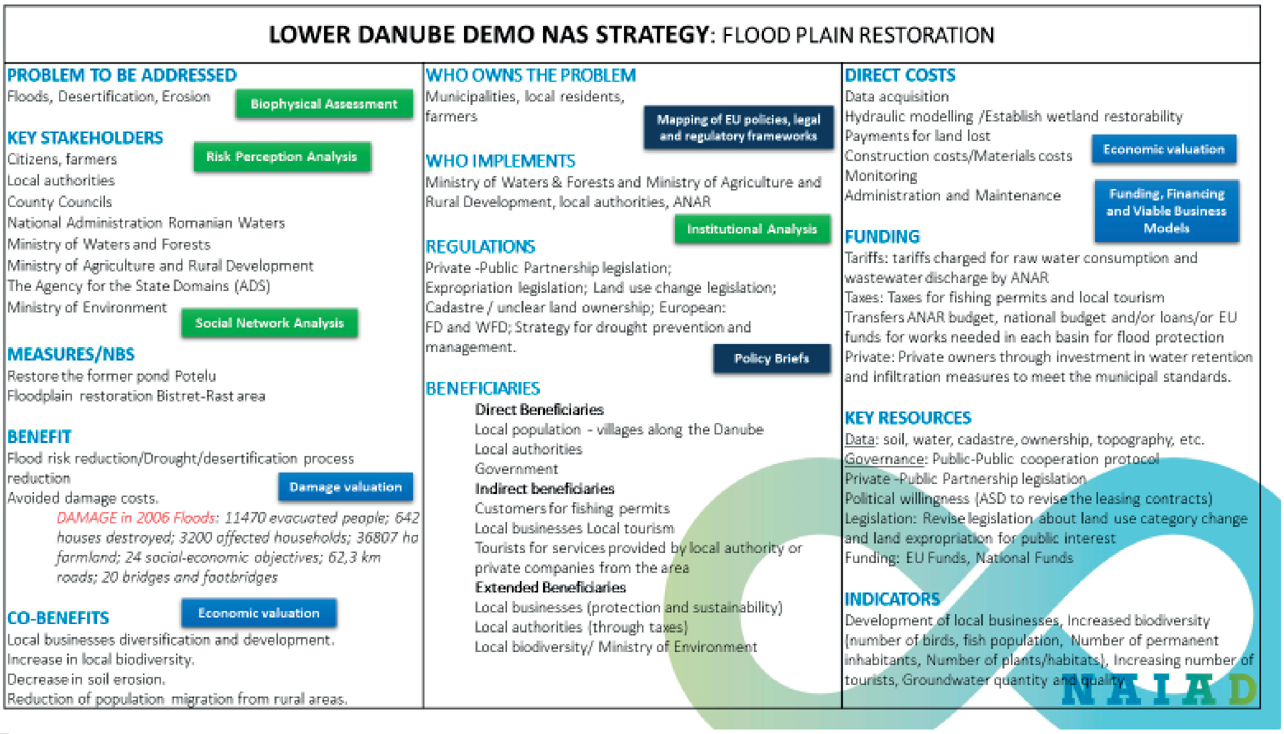

Figure 4: Example of the NAS Business Canvas applied to the Lower Danube.

4.3. A financing framework for water security

Third, through the financing framework for water security, as described by Altamirano et al. (2020). This financing framework further develops and tests for natural assurance schemes the "Better Business Case approach" (Smith and

Flanagan, 2001). This includes 5 elements of analysis a) the "strategic case" to demonstrates that the proposed nature based solutions (or strategies) are strategically aligned and are supported by a compelling case for change, b) the "economic case" ensures that a wide range of investment options, which in our case will compare green, hybrid and grey options, have been evaluated and that the preferred option optimises value for money, c) the "commercial case" ensures that any proposed procurement is commercially attractive and viable, which in relation to nature based solutions offers specific challenges, d) the "financial case" demonstrates that the preferred solution is affordable and can be funded, e) the "management case" provides assurance where processes and capabilities are in place to ensure that the preferred solution can be successfully delivered in our case, quite often as will be seen below, by public authorities since these are often the problem owners and most exposed directly (or indirectly through their citizens and businesses) to natural hazards.

NBS are facing several specific barriers for scaling up, including the difficulty to access funding and financing schemes from the lack of real examples providing evidence on their capacity and viability, and thus provide investor confidence and lower investment risks. Furthermore, making this type of projects attractive for private and impact investors requires a clear identification and quantification of the value proposition provided by these solutions, as well as a strong business case that ensures return of investment, particularly in the mid to long term. Most NBS projects fail to develop such a business case partly due to the limited data and evidence on the range of benefits provided by NBS, and their respective value. These projects also need to assess how the value generated – in our case by natural assurance services converted into viable schemes – through risk reduction and additional co-benefits can be captured and generate a series of revenue streams that makes them financially viable, similar to the business models developed for private projects providing goods and services. Identifying the "business model" for an NBS project – including a quantified value proposition, the elements required to deliver this value (resources and stakeholders), the costs of delivering this value, the range of beneficiaries and potential pool of clients and the associated possible revenue streams – will be an essential step to build a convincing business case that reduces the perceived risk by investors, also identifying the possible mix of funding sources to cover the whole range of lifecycle costs and also consider the opportunity costs.

5. Some case study results: what did we learn and do?

This section summarises some of the results from some our case studies. For reasons of space we only reflect on a number of them, namely the smallest and the largest case studies: the case of the Spangen neighbourhood in Rotterdam, which is being replicated in the Spanish city of Valladolid, the Thames, Lower Danube and the Medina del Campo case studies.

5.1. A CO-DESIGN PROCESS: PROBLEM OWNERSHIP AND LEGITIMACY: Example from the Lower Danube (Romania)

The Lower Danube case study covers an area of 250 km of the river. The strategy selected by stakeholders was flood plain restoration. Based on a structured process from the Stakeholder engagement protocol (see Annex 1), the main priority was to reduce the risk of floods and drought in the region. Stakeholders of the project (local and regional authorities, insurers, farmers, Watershed Management Authority, etc.) met with those responsible for the NAIAD project to discuss the most appropriate solutions to tackle the problems of the region, the direct benefits and co-benefits associated with these solutions. For this region based e.g. on the participatory modelling explained earlier, stakeholders identified the Nature Based Solutions preferred to reduce the risk, in this case the restoration of the Potelu pond and the restoration of the flood plains of the Bisret area were selected as a strategy. The direct benefits in this case are the flood risk reduction and the avoided damage costs, where the CAT Tool was implemented. Then, the associated benefits from the implementation of these solutions and the co-benefits associated to these solutions.

Local development, increased biodiversity, decreased soil erosion and reduced population migration to urban areas were identified as the key co-benefits. Then, in a facilitated process of co-creation, stakeholders identified who owns the problem, who implements the solutions and the regulations that would regulate the implementation of the solutions (direct, indirect and extended beneficiaries that will be benefited, based on the use of the NAS Canvas), as well as qualitative estimates on the direct costs of the implementation, as the planning, construction, maintenance, monitoring among others. The direct costs of the execution of the work, of the planning, construction, maintenance and monitoring of the solution and possible funding instruments, revenue flows and / or financing options were also identified and analysed. Data, governance, and revision of legislation regarding land use change were identified as key resources. Finally, a series of monitoring indicators were defined to evaluate the effectiveness of the solutions and the provision of co-benefits.

5.2. EFFECTIVENESS OF NBS: comparing options for flood and drought at large scale in Lower Thames (UK)

The Eco:Actuary toolkit was co-developed with the insurance industry and implemented in the UK Thames region with local authorities and land owners. During NAIAD we have held "Dragons' Den" type pitches with investors keen to develop green investment opportunities. These include investing in large scale NFM and drought friendly farming practices, such as regenerative agriculture, and using the //Smart: system to quantify the contribution of those investments to mitigate flooding and drought. We are also working with actuaries associations have also expressed an interest in a global climate risk index based on the Eco:Actuary global model. Finally a UK water supply company has invested in using the //Smart: technology developed during NAIAD to help advice farmers on best practices for reducing leachate using tillage and cover crops in drought-prone and nitrate-sensitive chalk aquifer areas.

The results of the monitoring and evaluation frame have shown that investment in Regenerative Agriculture is the most cost effective way of mitigating flood; if water stays on the land and is able to infiltrate, this very effectively reduces flood risk downstream. By improving infiltration, water remains available during seasonal droughts. Regenerative agriculture has significant co-benefits including reducing carbon emissions from ploughing and increasing soil biodiversity and organic matter. Increasing rainfall infiltration will reduce runoff and erosion, and thus preserve soil fertility and prevent pollution of the waterways from agricultural runoff.

5.3. POLICY FRAMING: Policy drivers to address water security in Medina del Campo (Spain)

In the case of Medina del Campo, both droughts and floods were analysed. The Groundwater Directive 2006/118/EC and the Water Framework Directive 2000/60/EC impose the obligation for the Duero River Basin Authority (DRBA) to assess the impact and damages from existing pressures and to take measures to restore the good quality status by 2027. In the case of the Medina del Campo Groundwater body, the main threats identified include lowering piezometric levels, diffuse agricultural pollution (NO_3), and elevated arsenic contents of lithological origin. A first measure established by the DRBA to address these pressures was a water transfer from the neighbouring Adaja River and the Cogotas reservoir to substitute groundwater by surface water for irrigation in the Adaja irrigation district (6,000 ha). As a result, a localised recovery on piezometric levels was detected in the surrounding area due to the double effect of stopping groundwater extractions and increased replenishment from surface water losses.

The NAIAD framework aimed to contribute to these challenges in the Medina case study. The study pursued to identify and assess possible Natural Assurance Schemes (NAS) that could help reduce water related risks while restoring the aquifers system status and functions. With this objective, a series of NAS strategies were co-designed with local stakeholders combining NBS and soft measures. The process followed the iterative steps set by the NAIAD stakeholder engagement protocol (Annex 1). The collaborative approach was combined with an analysis of their legal and technical feasibility by the river basin authority.

Two NAS strategies were considered for reducing vulnerability against drought risk while restoring the aquifers system status and functions in the Medina del Campo Groundwater Body:

1. Crop change towards drought resilient species, soil and water conservation practices, establishment of water user associations, abstractions monitoring and control and environmental awareness rising.
2. Aquifer recharge, establishment of water user associations, abstractions monitoring and control and environmental awareness rising.

The groundwater flow was simulated for three different climate scenarios and three different groundwater management scenarios: 1) Business as usual (BAU); 2) a reduction of Exploitation Index to 0.85 by year 2050 and beyond, and 3) a reduction of EI to 0.8 by 2050 (DRBA goal) and beyond. The last two models aimed to provide sensibility on the impact of small groundwater management changes. The main results were that groundwater management (through reducing the EI) has a much larger impact on piezometric recovery than climate change (through modified recharge of the aquifer).

The two NAS strategies proposed for coping with drought hazard risks in the Medina del Campo groundwater body were also economically evaluated under different scenarios following the economic cost-benefit analysis framework presented in Le Coent et al. (2020).

The climatic and socio-economic/regulatory scenarios considered were selected using a combination of expert-based and participatory co-development approaches. The evolution of the EU Common Agricultural Policy (CAP) subsidies was identified by stakeholders as a critical driver of land use change. Consequently, both a current CAP scenario and a more environmentally oriented CAP scenario were considered. Regarding climatic scenarios, a preliminary assessment of trends in average and maximum precipitation using the RPC 4.5 and RPC 8.5 IPCC projections (CEDEX, 2012) showed that no significant trends existed in any of the rainfall series to the project time horizon (2050), in line with the risk assessment results (Llorente et al., 2018). Consequently, only one climate scenario, based on the historical trends, was simulated (Calatrava et al., 2019).

The economic impacts of the NAS strategies in terms of reducing drought risk have been assessed using an agro-economic model calibrated to the technical, economic, and hydrological characteristics of the study area. This model simulates land and water allocation among cropping alternatives to improve the aquifer's conditions and to reduce drought risk in irrigated agriculture, under the different climatic and socio-economic scenarios considered, and computes several economic, social and resources use indicators. The method and results of the economic assessment of the impact of NAS strategies on the avoided damages is detailed in Calatrava et al. (2019).

Although the strategies' co-benefits have not been monetarily evaluated, the combination of the different analysis performed allowed for the qualitative and/or quantitative assessment of major expected co-benefits.

Identified co-benefits include an increase in water productivity, job generation and the profitability of agricultural employments, suggesting a greater potential for higher agricultural wages. Regarding the environmental co-benefits, both strategies would have similar impacts on the improvement of the aquifer's quantitative and qualitative status, although the artificial recharge in strategy 2 would accelerate the aquifer's improvement and would positively impact on some riverine ecosystems. Lastly, strategy 1 implies a less intensive farming than strategy 2, as crop rotations and less water-demanding crops are fostered, resulting in an environmental improvement of agricultural systems.

The results of the economic assessment show that the second strategy does not reduce drought risks but improves local riverine ecosystems, while the benefits of strategy 1 largely outweigh its costs, with a 3.17 benefit/cost ratio, even if the existing co-benefits were not considered (see Calatrava et al., 2019). However, strategies 1 and 2 are not conflictive but highly complementary and should be ideally combined to accelerate the aquifer's recovery and increase other environmental co-benefits. Our results also indicate the importance of considering an integrated value frame (Lopez-Gunn, et al., 2020).

5.4. REPLICATION: Football stadiums for climate with nature-based solutions: NAIAD flood mitigation in Rotterdam and drought resilience in Valladolid

Finally our smallest demo developed within the H2020 NAIAD project concerned flood mitigation in a neighbourhood of Rotterdam, Spangen. Here, an NBS was implemented which increases rainwater retention while reducing rainwater discharge to the sewage system. The neighbourhood did not have sufficient rainwater retention capacity, which is problematic during extreme rainfall events that are expected to become more frequent in the coming years. At the same time, the neighbourhood had been vulnerable in relation to drought (e.g. heat stress or degradation of foundations of buildings). As such, the municipality of Rotterdam concluded that the area required an additional 53,000 m^3 of water retention capacity.

To meet the need for the retention capacity, the municipality prepared a water plan for the neighbourhood. Part of this plan was the realisation of a pilot project 'Urban Water Buffer' (UWB) around a Sparta football stadium. The UWB relies on subsurface storage in which water is collected and stored during heavy rainfall events. Also, rainwater runoff from the roof of the stadium and from surrounding areas is collected, treated and recovered for irrigation. The project results in an increase of neighbourhood retention capacity of 1,500 m3 every 48 hours, which can contribute to flood as well as drought mitigation.

In addition to the empirical study of the implementation and decision-making process evolving around the implementation of the UWB, the NAIAD project assessed the economic impact of three strategies for flood mitigation in relation to the entire neighbourhood of Spangen Rotterdam:

- Grey, being a separated sewer system and permeable pavement.
- Hybrid, being a separate sewer system with natural retention and infiltration at public squares, including aquifer storage.
- Green, being only green infrastructure for retention and infiltration.

Critically, the analysis considered not just direct financial costs and benefits relating to the primary purpose of flood mitigation (which were designed to be equivalent in each option), but also considered a range of co-benefits that the NBS options produced. These co-benefits included health impacts, impacts on property values, heat mitigation, roof lifespan extension (for green roofs) and potable water system savings from water reuse.

The analysis found that the cost of implementation of grey solutions was higher (by 15 %) than that of NBS for the same level of risk management – therefore NBS are likely to be more cost-effective than grey solutions. Additionally, the co-benefits of the green option were estimated to be far higher than the flood mitigation benefits, making an attractive case for investment.

The solution is now in the process of being replicated in the city of Valladolid and the José Zorrilla Football Stadium, joining forces with the H2020 UrbangreenUp project in the same site, together with funding provided by the Partners for Water Dutch innovation fund and co-funding by the city of Valladolid, with the technical support of Aquavall, the local water company, the Real Valladolid Football club and the Duero River Basin Authority. This shows how nature-based solutions can mitigate flood and drought risks which are more likely under climate change scenarios while generating important co-benefits, made possible through the collaboration of cities, football clubs, local water companies and basin agencies, supporting innovations from European start-ups backed by the best scientific institutions.

6. Policy uptake and explotation

The NAIAD Project has focused on the potential that nature-based solutions and green infrastructure offer for future proof investment for climate change adaptation, to increase the resilience at both territorial and city scale to floods and droughts. This increased resilience is built on the bundle of avoided damages and co-benefits that nature can provide. We have introduced the concept of a Natural Assurance Schemes (NAS) that cities and regions can develop, by sharing a range of NAS tools and methods: tools like Eco:Actuary or the FEV for biophysical assessments, a participatory modelling frame to capture stakeholders values and perceptions, an integrated cost benefit analysis, the framing into the adaptive cycle, a business model canvas for natural assurance schemes and a financing framework for water security, which are all part of the NAS Methodological Assessment frame. We have also presented some of the results of their application to four of our nine demos located across Europe spanning different scales: from large scale like the Thames basin (UK), the Lower Danube (Rumania) or the Medina aquifer (Spain), and Rotterdam (Netherlands), including its replication to Valladolid (Spain).

At the end of the project experience a first NBS Dragons' Den and NBS Pitches, were held with our demos, with a "mock" exercise with real private and public investors in our final demo meeting in Copenhagen (Jan 2020), and what elements would be needed to turn this knowledge into lessons learnt and bankable natural assurance scheme viable projects.

Equally a series of policy briefs and guidelines have been developed. In the final months, a series of national roundtables have been organised in different EU countries (Spain, France, Romania, Sweden and Slovakia) to directly present some of our results but even more important, validate these results and frame them into the wider policy discussions currently under way on the draft EU adaptation strategy, the new draft Law on Climate Change and the EU Taxonomy on Sustainable finance. Here the focus has been to include in the conversation the role of NBS and potential natural assurance schemes in three gaps identified in conversations with DG Clima: the protection gap, the investment gap and the information sharing gap.

Ultimately NAIAD has provided a conceptual framework, a set of tools and methods and means for integration to have a better understanding on the role that nature based solutions can play for risk reduction and prevention, capitalizing on the assurance value of nature for both avoided damages and co-benefits, testing it in 9 demo cases at different scales and locations, and at different stages in the implementation cycle. As has been seen these frameworks and tools aim to support the integration of NAS into planning and implementation (gathering evidence of the effectiveness of the measures implemented) at different environments. The possibility to evaluate NBS will facilitate the incorporation of these solutions in, for example, river restoration plans, and therefore, funding for its implementation to convert them into real projects. Another key output of the project is a set of training materials on NAS implementation and assessment, through a MOOC (massive online Open course), that will be now complemented through an edited book with Springer currently in preparation.

7. Conclusions

In conclusion, the project started asking some questions, and now, after more than 3 years, we can respond to some of them:

First, in a context of climate change and land use change plus and increase of asset values and distributions, the level of losses is increasing significantly, posing a challenge to governments, cities, the insurance sector and citizens. Are NBS the solution? Can the design of natural assurance schemes better prepare and avoid potential costs? On the evidence from our results, all these questions have a positive answer.

Second, NAIAD demonstrates that NBS are an important part of the portfolio of risk reduction, increasing the resilience of the system while providing additional societal co-benefits. However equally NBS are not a silver bullet, sometimes a combination of NBS with other measures, including grey solutions could be the best option. Therefore, the answer to how we best develop locally adapted solutions in catchments and urban areas is through real evidence and by revisiting existing evidence. What is clear is a revised paradigm benefits from bringing in multi-disciplinarity, to better understand the nature of what are inherently complex problems. Here the correct integration of knowledge (and disciplines) is key, which is ideally suited to the properties of nature-based solutions that are inherently multifunctional. Our simulations also seem to indicate that NBS will be particularly well suited to frequent events, rather than the most extreme, thus increasing the overall resilience of the system. In prevention, we saw that NBS display their highest insurance value at the prevention stage against extreme events but also against more frequent events related to water risks.

Third, the possibility of evaluating NBS and NAS will facilitate the incorporation of these solutions in River Basin Management, River Restoration Plans, flood and drought risk planning and, therefore, the mobilization of resources for their financing, moving towards an adaptive management cycle that shifts the focus earlier into the risk management cycle into prevention.

Finally, one important insight learnt in the process was to identify that what normally is seen as a barrier, namely the different risk perceptions and ambiguity between the different stakeholders is in fact a latent opportunity for their uptake if these different perceptions are aligned. The mobilization of collective action to deliver risk prevention and reduction will be central and what until now were bundled as “transaction costs” need instead to be “unbundled” and understood for their enormous potential to help deliver collective action for risk reduction tapping in the value of nature for increased resilience and prevention.

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Annex 1: The Stakeholder engagement protocol - co-designing natural assurance schemes

In parallel to the technical work, the DEMOs organized several workshops with the local stakeholders where NAIAD partners co-developed with them same steps of the process for the effective implementation of NBS in their area.

The results obtained in these workshops were:

- The assessment of the risk perception in the area.
- Selection and validation of the solutions more suitable (including hybrids, grey...).
- The identification of the co-benefits associated to these solutions.
- The co-identification of indicators to monitor these solutions along the time and see if they are being effective in reduce the risk, provide co-benefits...
- Additional discussion on possible NBS-Strategies, the most effective combination of different solutions.
- And in the final workshop, co-identification of potential business models derived from the solution selected.

Box 1: The Stakeholder Engagement Protocol developed in NAIAD

A core operating principle of NAIAD is to proactively engage with stakeholders in the case studies throughout the application of its conceptual and assessment methodologies for Natural Assurance Schemes. The interdisciplinary nature of the whole approach fundamentally makes it relevant to a wide range of stakeholders, including decision makers, practitioners, scientists, end users and communities. Each stakeholder will have their own knowledge and perspectives of the integrated physical, social, cultural and economic systems in which the case study is situated, with all these needing to be shared and synthesised during the assessments. In addition, the stakeholders served an important function in terms of "road testing" and validating the tools and methods developed and presented in this article.

To fulfil this principle, various participatory modelling techniques and approaches were applied. The selection of the relevant approaches for each case study depended upon the contextual realities and the specific problems being addressed. However, a general set of guidelines compiled into a "stakeholder engagement protocol" were developed to serve as a practical source of guidance for case study practitioners, while ensuring some standardization and coherence/comparativeness of the process across the case studies.

The Stakeholder engagement protocol was composed of ten iterative and sequential steps which set the framework, objectives and proposed the range of methodologies that could be applied to advance through the participatory data collection, co-design, modelling and validation activities. (Click here to see more about The Stakeholder Engagement Protocol).

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730497. We also want to thank the Duero Basin Agency as strong supporters for this project.

For this paper we have also drawn on the work of many NAIAD colleagues. As a non-exhaustive list we want to thank in particular:

Altamirano, M. and Basco, L., DELTARES (Netherlands)
Calatrava, J., and Manzano, M., UPCT (Spain)
Darte, K. and Peña, K., Field Factors (Netherlands)
de la Hera, A. and Llorente, M., IGME (Spain)
Pagano, A. IRSA, (Italy)
Piton, G. and Tacnet, J.M., INRAE (France)
Scrieciu, A., GEOECOMAR (Romania)
van Cauwenbergh, N., IHE-Delft, (Netherlands)
van der Keur, P., GEUS, (Denmark)

The concept of a "traffic event" in EU jurisprudence

The Court of Justice of the European Union determines that a person falling due to a patch of oil spilt in a garage by a vehicle is a traffic event

Decision of the Court of Justice of the European Union of 11 December 2019

José A. Badillo Arias
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Consorcio de Compensación de Seguros

1. Introduction

To be able to refer to an accident as covered by the Law on civil liability and insurance in the use of motor vehicles, which was endorsed by Royal Decree-Law (RDL) 8/2004 of 29 October (the "LRCSCVM" for the Spanish), it must be categorised as a "traffic event" caused by a "motor vehicle". If these two circumstances are not attendant, the special regulatory framework that is established in the LRCSCVM and its regulations does not apply.

What we are dealing with are the two most basic and decisive circumstances in civil liability from road traffic. For this reason, doctrinal commentaries have questioned the fact that both of these concepts, which determine the scope of application of the law, have been relegated by Article 1.6 of the LRCSCVM to regulatory implementation of it.

As matters stand, both concepts are being studied by EU institutions with the aim of adapting the regulatory framework of Member States to the latest jurisprudence of the Court of Justice of the European Union, which was initiated by the CJEU Judgment of 4 September 2014 (the Vnuk case), which was followed by the CJEU Judgments of 28 November 2017 (the Rodrigues de Andrade case), 20 December 2017 (the Núñez Torreiro case), 4 September 2018 (the Juliana case), 15 November 2018 (the Balcia Insurance case), 20 June 2019 (the LDA case) and the Decision of 11 December 2019 (the Zurich Insurance case), which is the subject of this commentary.

These court decisions are framing the concepts of "motor vehicle", which is in fact defined in the 2009 codified Directive and, above all, that of "use of vehicles", which is not defined in the Directive, although, as we shall go on to examine, the Court of Justice of the EU is working on outlining it, given that, as it stated in the CJEU Judgment of 4 September 2014 (the Vnuk case), this is an independent concept, the interpretation of which cannot be left to each Member State to determine. This assertion is perhaps the one which has, as a result of

The definition of a traffic event in the regulations must be associated with driving vehicles, even if their engine has stopped, because such cases can also entail a risk for road users (let us imagine for a moment those accidents that are caused by not activating the vehicle's safety mechanisms properly, which causes them to move without a driver).

It is therefore sometimes not necessary for the vehicle to be moving in those places which we have mentioned for it to be possible to speak of traffic accidents. In this case the decisive issue will be that events should be within the realm of traffic, i.e. they should be part of traffic risk. The most everyday examples are vehicle fires which cause damage to other vehicles or property, motorbike falls or vehicles moving without having been started yet with the same effect, loss that occurs on getting into or out of a vehicle, etc.

this judgment, led to courts in the Member States seeking preliminary rulings on various issues relating to this matter, which have in turn brought about the judgments listed in the preceding paragraph.

For these reasons, on 24 May 2018, the "Proposal to amend Directive 2009/103/EC of the European Parliament and of the Council of 16 September 2009 relating to insurance against civil liability in respect of the use of motor vehicles, and the enforcement of the obligation to insure against such liability" was brought before the European Commission.

2. The concept of a "traffic event"

The notion of a "traffic event" or, to use the CJEU's terminology, "use of vehicles", is (as already stated) currently subject to review by European institutions to adapt the regulatory framework of Member States to the latest jurisprudence of the Court of Justice of the EU. Therefore, after examining the matter of the Spanish legal system, we shall refer to these CJEU judgments, as well as to the Proposal to amend codified Directive 2009/103/EC relating to insurance against civil liability in respect of the use of motor vehicles.

2.1. Definition of a "traffic event" in Spanish law

The definition of "traffic events" is regulated in Article 2 of the currently effective Compulsory motor car third-party liability insurance (MTPL) Regulations. Paragraph one, which lays down the general rule on what "traffic event" should be taken to mean, retains the same wording as the previous Regulations. It thus once again refers to the risk created by driving motor vehicles and says that "traffic events are understood to mean those arising from the risk created by driving the motor vehicles that are referred to in the preceding paragraph".

Section two of paragraph one contains the spatial element in the definition. It indicates the places where traffic accidents or events can happen: garages and carparks, public and private roads or land suitable for vehicle use, in both an urban and inter-urban context, as well as roads or land commonly used even if they are not suitable as described.

We note that, with respect to the regulations which they replaced, the reference to garages and carparks is kept, since manoeuvres at the start or end of the drive generate minor risks which, though debatable in certain cases, such as on getting into or out of a vehicle that is stationary or a blow involving a vehicle door, fall within the scope of driving and are generally held to be traffic events as a result.

It can be seen that, given such a broad definition, in principle and has had been the case previously, it is unlikely that any accident caused by a motor vehicle would stand outside the scope of application of the special regulatory framework that we are discussing. Only in those cases where vehicle access is virtually impossible or circumstances that are expressly excluded as traffic events under our current regulations, as is very common with respect to industrial or farming activities, will they not fall within the scope of traffic events.

In this regard, doctrine and jurisprudence have taken the view that the concept of a "traffic event" is of a *de facto* nature where, to define it, a complex set of factors needs to be taken into account, such as the vehicle type in each case, the activity which they are used for and the site where the loss event takes place. The general rule is that traffic events (which can be regarded as such for our purposes here) are linked to the dynamics that are characteristic of the motor vehicle itself and its movement in spatial terms for the transportation ends which are involved in them.

Whatever the case, the definition of a traffic event in the regulations must be associated with driving vehicles, even if their engine has stopped, because such cases can also entail a risk for road users (let us imagine for a moment those accidents that are caused by not activating the vehicle's safety mechanisms properly, which causes them to move without a driver).

It is therefore sometimes not necessary for the vehicle to be moving in those places which we have mentioned for it to be possible to speak of traffic accidents. In this case the decisive issue will be that events should be within the realm of traffic, i.e. they should be part of traffic risk. The most everyday examples are vehicle fires which cause damage to other vehicles or property, motorbike falls or vehicles moving without having been started yet with the same effect, loss that occurs on getting into or out of a vehicle, etc.

Even though our case law is not unanimous in this respect, we can say that, generally speaking, such cases are understood to be traffic events, either because it is considered that they are part of traffic risk (electrical faults, short-circuits, parking the car without applying the safety mechanisms, etc.) or on account of the effects of the criterion for assigning liability in the LRCSCVM, which compels the insurer of the person originating the loss to prove, for example, that a vehicle fire for which they are liable was attributable to *force majeure*, the action of a third party or the exclusive fault of the victim.

2.2. Exceptions to consideration as traffic events

Article 2.2 of the MTPL Insurance Regulations governs cases that stand outside categorisation as an accident or a traffic event, such as taking part in sporting events, performing industrial or farming work, travelling on roads not suited for traffic and using the vehicle as a means of committing intentional crimes.

These are situations where, although the accident occurs with the involvement of a motor vehicle (and even in some cases in a place that is suitable for traffic), there is express exclusion in the regulatory norm on various different grounds, since they are viewed as being removed from traffic activity. The reason for exclusions of this kind is clearly warranted, which does not mean that it is immune from various problems being raised in practice on account of the vast assortment of cases that emerge. Here we are referring to activities or events where there is no intention to move as traffic.

We should note that some of these exclusions are currently open to debate as a result of legal precedents that have emerged from the Court of Justice of the European Union. Thus the exclusion as a traffic event of motor vehicles travelling on roads or land where the legislation stated in Article 1 does not apply runs counter to what is determined in the CJEU Judgment of 20 December 2017. Let us not forget that the jurisprudence of the Court of Justice of the EU constitutes Community Law and therefore compels the legislating state to amend any legal provision that opposes it according to the interpretation offered by said court. Likewise judges are also obliged to apply the jurisprudence pronounced by the Court of Justice in its interpretation of Community Law.

2.3. The influence of EU jurisprudence

With regard to this matter we have to stress the influence which the jurisprudence of the Court of Justice of the EU has been exerting in favour of treating these accidents as traffic events, starting with the CJEU Judgment of 4 September 2014. In this judgment the European Court indicated to us that if a vehicle performs a function that is usual for it, then we are dealing with a traffic event.

There have subsequently been two pronouncements by the Court of Justice of the EU regarding this same question. The first, which was raised by a Portuguese court, was decided in the CJEU Judgment of 28 November 2017. This concerned a claim by the aggrieved parties in connection with a female Portuguese citizen who had died in an accident that occurred on a farm where she was working.

In this case she was crushed by a tractor that had been halted on a flat earthen path with the engine running to operate a herbicide spray pump. The EU Court concluded that losses caused by work machine vehicles should only be covered by the MTPL insurance when they are being used as a means of transport, which was not what happened in this case.

The second case, which was pronounced on in the CJEU Judgment of 20 December 2017, relates to a matter referred for a preliminary decision by a Spanish court (the Albacete Provincial High Court). The facts concern an accident caused by a lieutenant in the armed forces who was in a vehicle when he was taking part in night-time military exercises in a practice area located in Chinchilla (Albacete).

In this case the EU Court held that the military vehicle was being used as a means of transport at the time when it overturned and therefore that the concept of "use of vehicles" in Article 3 of Directive 2009/103 should be construed in the sense where it contradicts national legislation (Art. 2 of Royal Decree 1507/2008), which allows the exclusion from MTPL insurance cover of losses caused by driving motor vehicles on roads or land that are "not suitable for vehicle use", except for those which, though not suitable as described, are nevertheless "commonly used".

More recently the CJEU has again pronounced on this matter. This was in the CJEU Judgment of 15 November 2018. In this case, the European Court decided on an issue raised by a Latvian Court, which asked it whether the concept of "use of vehicles" regulated in the 2009 codified Directive includes a situation such as that in the main litigation, i.e. the opening of the doors of a parked vehicle which causes damage to the vehicle that was next to it. In this judgment the CJEU concludes that "Article 3 of Directive 72/166 should be interpreted in the sense that the concept of 'use of vehicles' to which the abovementioned provision refers includes a situation where the passenger of a vehicle parked in a carpark strikes and damages the vehicle parked next to it when they open the door of the initial vehicle."

In 2019 there were two other pronouncements by the CJEU. The first of them was referred by Spain's Supreme Court and concerns the damage caused by the fire suffered in the electrical circuit of a vehicle acquired by its owner only days beforehand, on 20 August 2013. At the time when the fire occurred, at 3:00 hrs on the day in the court records, the vehicle was parked in the garage of a single family home owned by the company Industrial Software Indusoft S.L., where it had been parked without being driven for more than twenty-four hours. The Supreme Court asked the EU Court whether an interpretation contradicts Article 3 of Directive 2009/103/EC which includes the damage caused by the fire in a parked car in the compulsory insurance cover when the fire originates from the mechanisms required for the vehicle to perform its transport function.

In its judgment of 20 June 2019 the CJEU accepts that a situation counts within the concept of "use of vehicles" where a vehicle parked in a private garage burns and causes a fire that originates in its electric circuitry and damages the building, even though the vehicle has been stationary for over 24 hours at the time when the fire breaks out.

The CJEU holds that parking and the period in which a vehicle is stationary are natural and necessary states that are an integral part of its use as a means of transport. As a result, the vehicle is in principle being used in its role as a means of transport while it remains parked between two journeys.

The second matter heard by the EU Court in 2019 relates to a person falling over due to a patch of oil in a garage, which is the object of this commentary and so we shall analyse it in section three of this article.

2.4. Amendment of the Motor Vehicles Directive

Having looked at the latest CJEU judgments, we should note that the 2009 codified Directive does not establish a definition of "use of vehicles". For this reason it is the CJEU which is weaving together its case law on this matter and stating in some of its decisions that, on the one hand the concept of "use of vehicles" represents an autonomous concept in EU Law, where its interpretation cannot be left to determination by each Member State, while on the other hand the EU legislator has constantly pursued and stiffened its resolve to protect the victims of accidents caused by these vehicles.

This has meant that the key reason for the Proposal to amend the Directive cited is to reflect the case law of the EU Court. Thus the Proposal of 24 May 2018 says that: "A number of judgments of the Court of Justice of the European

Union, mainly those in the "Vnuk", "Andrade" and "Torreiro" cases, have clarified the scope of the Directive." It goes on to add that "... to ensure legal certainty and clarity, the present proposal codifies the Court jurisprudence in EU legislation. This ensures uniform implementation of the Court case law in national law".

As we have seen, the CJEU bases itself on a very broad understanding of what "use of vehicles" should be taken to mean bearing in mind the role characteristic of each vehicle, regardless of the road or terrain on which it travels or in cases of getting into or out of them. It has also held that damage caused by a stationary vehicle falls within the concept of "use of vehicles" if its purpose is as a means of transport (CJEU Judgment of 20 June 2019).

For this reason the Proposal to amend the 2009 Directive adds a continuation to paragraph 1 of Article 1 therein, and determines that "motor vehicles are intended normally to serve as means of transport, irrespective of such vehicles' characteristics, and that the use of such vehicles covers any use of a vehicle consistent with its normal function as a means of transport, irrespective of the terrain on which the motor vehicle is used and of whether it is stationary or in motion".

At the time of writing, we are immersed in this legislative process and cannot guess what the future holds for this proposal, since there is a whole raft of finer points that need to be ironed out and it seems that there is no consensus among Member States yet.

3. Analysis of the Decision of the Court of Justice of the European Union of 11 December 2019

In this case the lady owning a motor vehicle had MTPL cover with Zurich Insurance. The vehicle was parked normally in a private garage space belonging to the owner. Due to its mechanical condition, the vehicle was leaking oil and other fluids, which ended up spreading out into neighbouring parking spaces.

On 19 September 2015, the claimant in the case was going to pick up her own vehicle which was parked in one of the adjacent spaces, when she slipped on a patch of oil and sustained bodily injury after falling onto the ground. On account of this she filed an out-of-court claim with the insurer of the vehicle which was leaking, and after it turned her down she brought a claim against the owner of the vehicle and her insurer, alleging that she had been injured as a result of a traffic accident and claiming for damages for the bodily injury and property damage which she had sustained from falling over.

The court of first instance found in favour of the claimant, since it understood that the case indeed concerned a traffic event because using a vehicle in garages is a situation that is covered as such in Spanish law. After this ruling, both the owner and her insurer filed an appeal with the Zaragoza Provincial High Court, which in turn referred the matter for a preliminary decision to the CJEU.

With regard to this matter, the Zaragoza Provincial High Court understood that the issue at the heart of it turned on determining whether, in light of Article 3 of Directive 2009/103/EC, a situation such as that in the core litigation can be considered to be a "traffic event" (where ordinary use of the vehicle leads to it leaving a patch of oil both at the space where it is normally parked and over the surrounding area due to its mechanical condition and this produces third party risk) and can therefore fall within the orbit of the obligation to insure motor vehicles.

In its recitals, and as it had already done in the CJEU Judgments to which we have referred in earlier paragraphs, the EU Court alludes to the twin aims in the motor vehicles insurance directive (2009/103/EC) of guaranteeing, on the one hand, the free movement of both vehicles normally parked on EU territory and the persons occupying them, and on the other hand, that the victims of accidents caused by such vehicles receive comparable treatment wherever the accident has taken place within the European Union.

Furthermore, as it already said in the CJEU Judgment of 20 June 2019 (the vehicle fire), it maintains that developments with regard to this legislation make it clear that the EU legislator has constantly pursued and stiffened its resolve to protect the victims of accidents caused by such vehicles.

So, to justify its final decision, the CJEU makes reference to previous judgments concerning this matter, saying that the fact that a vehicle which has taken part in an accident was stationary at the time when it took place does not in itself rule out the possibility of the use of the vehicle at the time being included within the scope of its function as a means of transport, and therefore within the concept of "use of vehicles" for the purposes of Article 3, paragraph one, of Directive 2009/103/EC. Neither is it decisive whether the engine of the vehicle in question is running or not at the time when the accident takes place (CJEU Judgment of 20 June 2019).

Finally, in response to the preliminary decision sought, it rules that Article 3, paragraph one, of Directive 2009/103/EC should be construed to mean that the concept of "use of vehicles" therein should be taken to include a situation where a vehicle that has manoeuvred or been parked in a private garage causes an accident in the garage by dint of its function as a means of transport.

4. Conclusions

In the Decision of 11 December 2019, the CJEU again refers to what "use of vehicles" should be understood to mean and, as we have seen, broadens this concept, once more endowing it with the kind of proportions to extend to and protect traffic accident victims. It will thus be unlikely that any accident caused by a motor vehicle can escape being considered as a "traffic event" covered by compulsory civil liability insurance or, if this does not exist, by the guarantee fund in the country where the vehicle concerned is normally parked.

As can be noted, not just from this decision, but also from all those where it has ruled on this matter, the EU Court confers a very broad interpretation on the concept of a "traffic event" and even includes situations where the vehicle is parked, driving on roads unfit for this purpose, or engaging in farm-work, etc. Such an extensive interpretation is to some extent at loggerheads with the provisions of Article 2 of the MTPL Insurance Regulations, which lays down certain exclusions which would run counter to EU jurisprudence.

This situation produces a certain degree of legal uncertainty for those of us among the various stakeholders who have to interpret these matters. Moreover, these decisions could have an impact on how we insure certain vehicles in Spain. At the moment, what we might consider to be business, industrial or farming activities are covered by means of liability insurance that is specific to them and separate from MTPL insurance. In other cases, these vehicles are covered by the business operation liability insurance of the enterprise for which they perform such tasks. Obviously, besides performing these activities, when these vehicles travel on public, private or commonly-used roads, they must also have the relevant MTPL insurance.

In any event, let us hope that work concludes soon on amending Directive 2009/103/EC which, as we said earlier, among other things is aimed at integrating EU jurisprudence on the "use of vehicles". Thus, once the amendment has been approved, we shall have to adapt our legislation to accommodate the provisions in it, which will lead to current contradictions being clarified and, most importantly, the necessary legal certainty will be achieved.

OECD report on "Responding to the COVID-19 and pandemic protection gap in insurance"

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On 28 May 2020, within its series of publications and notes on policies to respond to the coronavirus (SARS-CoV-2) and the disease it produces (COVID-19), the Organisation for Economic Cooperation and Development (OECD) has released its note headed "Responding to the COVID-19 and pandemic protection gap in insurance".

This is a timely note that gives context to all the issues currently on the table in the debate on how to respond from an insurance standpoint to this type of risk which had never previously risen up with such force in our life-times.

> From the insurance point of view, the key problem in the present situation which COVID-19 has brought about is business interruption losses without physical damage, which has resulted from the government taking preventive measures in a bid to stop the virus from spreading and had a huge impact on sectors such as commerce or hospitality, while threatening the viability of thousands of companies, particularly small and medium-sized enterprises (SMEs), in the process.

From the insurance point of view, the key problem in the present situation which COVID-19 has brought about is business interruption losses without physical damage, which has resulted from the government taking preventive measures in a bid to stop the virus from spreading and had a huge impact on sectors such as commerce or hospitality, while threatening the viability of thousands of companies, particularly small and medium-sized enterprises (SMEs), in the process. In certain jurisdictions, this has put insurers under some degree of pressure from industry associations or even governments to cover this risk, which has exposed the fact that pandemics are either one of the exclusions typical of insurance policies or else they are a risk that can be insured separately, although its take-up is not very common. In some cases pressure of this kind has led to legal action.

The industry justifies its position by claiming that risks cannot be covered after the materialisation of an event that has not been included and rated beforehand. Retroactive coverage can seriously compromise the solvency of insurers given that, both on a global scale and in national markets, the potential cost of these business interruption losses substantially exceeds collected premiums in this line of insurance. Besides this economic reason, there is also a legal one: if losses not agreed under contract are covered, then these contracts are not being adhered to, which leads to legal uncertainty. Therefore, national supervisors of the major markets concur in asking insurers not to cover losses of this kind that are not under contract.

The industry has in fact responded in many different ways to this crisis: from postponing or partly refunding premium payments for the duration of the lockdown period to setting up solidarity funds (which are sometimes on an extremely substantial scale) to look after those segments that are most affected by the crisis, such as health-workers, the hospitality sector, etc. In the note, we can find several examples of this approach and, in the "News" section of this edition of the magazine, we can learn about how the Consorcio de Compensación de Seguros is collaborating to alleviate the situation from the Spanish insurance standpoint.

What this crisis has triggered is a debate on how insurance might cover losses in future pandemics. In some jurisdictions (the United States, the UK, France or the EU as a whole) they are beginning to give consideration to approaches similar to those taken for other risks with a high business interruption loss component, such as terrorism.

The key issues which programmes of this kind would have to tackle would be:

- Cover for business interruption loss without physical damage (non-contingent business interruption, a problem which insurers or systems that cover terrorism risk already face). To date insurance models have focussed more on morbidity and mortality risk rather than lost profit from business interruption.
- The potentially astronomical cost of losses, which would mean premiums being very unattractive to potential policyholders.
- A pandemic possibly affecting the whole world on account of both the spread of the virus or vector and/or governments simultaneously taking measures in several different jurisdictions, which would limit the options for diversifying exposure geographically and dilute the potential for reinsurance to spread and offset losses across various territories, which would also hike the cost of reinsurance.

There should also be several different possibilities for achieving broader coverage for this class of risk which are not mutually exclusive. The first would be to involve some kind of automatic extension to cover this risk in business interruption policies. The OECD recognises that, in catastrophe risk coverage schemes, those which, like the Spanish one, have this type of automatic extension manage to achieve broader coverage levels than those which cover these risks on an optional basis. The second would be to ensure public sector participation in the form of a backstop to cover insured losses beyond a certain level stated, for example, in terms of percentage points of GDP. This way, there would be protection and a market for this risk and cover would be guaranteed in the more extreme situations. And the third would be to require more ambitious continuity planning, by both the government and insured companies, which would make for better risk management. Plans of this type should include measures to facilitate working from home or making insurance cover conditional upon a certain level of investment in public healthcare, which would allow a more effective response to these threats.

As has already been noted, there is a natural parallel between possible solutions of this kind and the programmes for covering catastrophe and/or terrorism risks, and the OECD report makes a comparative review of these, which naturally includes the Spanish scheme. Yet, here we should point out something that is extremely important and which concerns the capacity that this kind of insurance solution would require: it would have to be of a substantially greater magnitude than it is at the moment in programmes to insure catastrophes. The note reminds us that business interruption losses from COVID-19 for SMEs alone in the United States may amount to as much as twice the cost of total losses caused by the East Japan tsunami in 2011.

Living in interesting times

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There is a more or less apocryphal legend which suggests that the ironic aphorism “may you live in interesting times” originates from a 17th century Chinese curse. Whatever its source, the fact is that the present at the Consorcio de Compensación de Seguros (CCS), both for the institution and those who are part of it, has been an almost continuous stream of “interesting times” over the past few months, from a succession of very significant loss events — starting with the cut-off low of September 2019 (which was the inspiration at the heart of the previous edition of our magazine) and ending with the low-pressure area known as Storm Gloria in January 2020 — to the crisis triggered by the global COVID-19 pandemic, which has brought new challenges for both the CCS in particular and society at large since March 2020. Over the next few lines, we describe our experience over these past few months at the CCS and what measures we have taken to ensure that we can always keep providing the solution that insured people and companies in Spain deserve.

After much suffering and sacrifice by many sections of the society in which we live, most particularly, the healthcare sector, it is making good progress towards overcoming the pandemic and along the road to recovering the levels of economic activity which we saw before. As ever, the CCS wants to be a part of the solutions that help society negotiate this awkward and uncertain path.

Together with 2009 and 2011, 2019 was one of the three most unique financial years for the CCS in these two decades of the 21st century.

The special nature of 2009 was due to extraordinary wind events: let us recall that the year opened with the biggest windstorm in the history of the CCS (Cyclone Klaus in January) and the strictly urban tornado which hit the city of Malaga in February, this being similarly the most serious in our experience. The two events led to more than 281,000 wind losses at a cost of 515 million euros (M€).

The second special year was 2011 on account of the Lorca earthquake of 11 May. This was the most devastating earthquake which we have had to deal with, which in short produced 33,000 losses and a pay-out of some 487 M€ in compensation to those insured.

Irrespective of the numerous bouts of extraordinary wind storms, we can in fact claim that 2019 owed its exceptional nature to what has always been held to be the “star” among the risk covered by CCS: flooding.

2019 saw the flood with the largest number of claims in the whole of the 66-year history of the CCS as an insurer of catastrophe risk. The cut-off low (or closed upper-level low) which basically, though not exclusively, struck southern and eastern Spain in September 2019, prompted 69,500 claims that had to be handled by the CCS and cost over 460 M€.

Although what happened in September was in itself enough to label the financial year experienced by the CCS as exceptional, two further, highly significant, aspects must also be mentioned to give a good idea of the intensive and sustained effort which our organisation had to make over that particular period.

On the one hand, the cut-off low in September 2019 was preceded by a flurry of summer floods, which meant that when it arrived the network of partnering adjusters and claims handlers at the CCS was fully occupied with dealing with these floods.

The floods in the middle zone of Navarre (mainly Tafalla, Olite, Pitillas and Pueyo) from torrential rains and the overflowing of the river Cidacos shook the inhabitants of a geographical area, who were unaccustomed to events of this kind. Losses generated over 2,000 claims, many of them involving very severe damage, and compensation paid out of more than 25 M€.

These floods were followed by several summer storms in Barcelona and northern Tarragona between 16 July and 15 August, which gave rise to over 2,300 claims at a cost of 7 M€.

Immediately afterwards, in the last third of August, successive floods occurred in Alicante (more than 1,200 claims costing 3 M€), Madrid (floods in Arganda and Fuenlabrada, with 3,000 claims and damage of over 10 M€) and Toledo, the Balearic Islands, Murcia and Castile León (1,400 claims and 3.6 M€ in damage).

To sum up, the prelude to September’s cut-off low comprised a whole host of some 10,000 losses that happened in the weeks leading up to it at a cost of 50 M€.

On the other hand, the cut-off low was followed by a four-month period from October 2019 to January 2020 of constant flood, including coastal floods and wave battering effects, with Catalonia being hit by another cut-off low in October, bringing almost 6,000 claims at a cost of 49 M€.

Following this, a third cut-off low entailing less serious consequences affected a large part of the Levant, prompting 1,350 claims and compensation pay-outs totalling 6 M€.

On top of this, in December, floods arose in a broad dispersion of places such as Reinosa, in Cantabria, and several locations in the provinces of León, Palencia, A Coruña, Pontevedra, Cáceres (the river Jerte burst its banks), Cordoba and Jaén on account of Storms Daniel, Elsa and Fabien, which together generated 6,000 claims at a cost of 38 M€.

The run ended with the devastating “Storm Gloria” in January 2020, which has thus far brought 16,000 more claims costing an estimated 165 M€.

In round numbers, there were almost 30,000 more claims immediately after the September cut-off low, which cost approximately 260 M€.

As a result, the CCS has made a sustained effort over several months to process more than 110,000 claims costing a combined 770 M€, of which around 70,000 claims and 460 M€ concern the central element in the period, namely the historic cut-off low of September 2019.

It is self-evident that a high-impact loss rate such as that which took place in 2019 forced the CCS to take exceptional organisational measures to be in a position to provide a swift service to protect the insured victims in their thousands. We can encapsulate how the handling of compensation was reinforced in five aspects.

Firstly, the September cut-off low put the system for receiving compensation claims and recording them digitally to the test. On 20 September 2019, the CCS received and logged the record figure of 9,960 claims filed in a single day via the institution's call centre and website. The CCS also provided the insured with the chance to file their claims by phone and directly on the premises offered by the council of the worst-hit municipality in the Murcia region (Los Alcázares).

Secondly, the cut-off low put strain on the institution's adjustment service capability: the CCS deployed a little over 400 loss adjusters (another historical record) to appraise insured damage. The scattering of losses over such a wide area also represented another challenge.

Thirdly, given that there were almost 70,000 claims, the CCS started up an original "universal" shared claim management system among all the handling teams from the headquarters and every one of its 17 territorial offices. On the other hand, the CCS centralised the perennially and especially delicate task of dealing with personal injuries from the floods using an *ad hoc* team of handlers to enable the relatives of the deceased to receive priority and wholly personal care.

A fourth aspect is that the CCS asked every insurer to designate somebody to act as a point of contact with the CCS and both provide documentation and clear up queries, thus avoiding the need to approach insured catastrophe victims. The willingness and speed of action of these contacts deserves special mention here, as does the smoothness of cooperation between the insurers and the CCS, all of which redounded to the benefit of the insured in common to the two parties.

Finally, the CCS sanctioned specific criteria to assess losses and handle claims that were tailored to match the exceptional magnitude of the flood and to safeguard the interests of those insured.

Given the harshness and intensity of the six months from July 2019 to January 2020, it is only fair to stress how the sustained effort which the CCS invested as an organisation was at all times met with very steadfast understanding and collaboration on the part of the insurers and insurance agents and brokers, as well as the associations representing them. This attitude was further proof of the merits of public-private partnership, which is the hallmark of Spain's insurance system.

Even so, over the first few weeks of 2020 it became evident that another problem on a hitherto unheard of scale was increasingly taking centre stage: the spread of the SARS-CoV-2 virus and its manifestation in the form of the disease COVID-19. With the declaration of a state of emergency on 14 March and the imposition of a lockdown to limit the spread of the disease, the activity of the CCS as well as the whole of society has been hampered and equally extraordinary measures have had to be taken. We can divide these measures into two blocks: firstly those which the CCS has taken to provide support for the insurance industry and the insured in this situation, and secondly those which the CCS has taken to ensure the continuity of its services.

Within the first block, the initial measure came in the form of a decision by the presidency of the CCS to make an exception throughout the duration of the state of emergency and up to one month afterwards, whereby the rules have been changed to allow insurers to postpone payment of the extraordinary risk surcharges on policies renewed during this period. This means that the facilities for paying the insurance premium which insurers might grant to their insured to alleviate any liquidity problems which they could experience on account of the pandemic are being backed up by the CCS by extending the facility to payment of the loading included in the insurance premium receipt.

At the same time the decision stipulates that for the duration of the exception period the postponement or splitting up into instalments of payment for premiums and loading in favour of the CCS shall not be grounds for it turn down claims. In cases where there is doubt in the course of handling compensation pay-outs as to whether the postponement of paying the premium and the loading derives from a facility granted by the insurer in the context of the pandemic or is by reason of failure to comply with their obligations on the part of the insured outside the context of the exception, the CCS can quickly clarify any queries via its previously mentioned network of effective contacts designated by the insurers.

Beyond this measure, which will be very short-lived, the CCS has been authorised by the Government under a Royal Decree-Law to provide re-insurance for credit insurance. This measure increases the likelihood of entrepreneurs who sell their products on credit being able to find insurance cover in the market when they would not otherwise be able to do so via the companies that provide such insurance due to the strains on the economy which the pandemic is causing. The measure is essentially directed at removing obstacles to financial transactions and endowing business arrangements with security. It is an instance of the kinds of temporary support measures for the industry "under circumstances when the market needs it" that is described in the Legal Statute of the CCS and which was already resorted to in 2009 in the context of the economic crisis which emerged from 2007-2008 onwards.

In the context of the second block, the CCS has benefited from its substantial progress in implementing its digital transformation plan by having its entire complement of staff working remotely within record time. This is to the extent that the number of settled claims in April was similar to the figure for previous months, which were very busy. Under these digitised procedures, claims are filed with the CCS by the insured (or via either insurance companies or brokers acting on their behalf or insurers) by ringing the CCS call centre or over the internet using our entity's website. They are then prepared for immediate and orderly distribution to adjusters using a system that geo-references the location of the case affected by the extraordinary risk. Delivery of the vast number of valuation assignments to adjusters is performed on a web-based communication platform through which the adjusters submit their report and the digitised insurance contract. In this way the final handling procedure for adjusted claims is managed via a system that is shared among all of the handling teams at the 17 territorial offices and in the central services area of the CCS.

The system has basically enabled all claims to be managed remotely by all of the handlers from the first day when the CCS decided to suspend work at its offices and all of its employees subsequently left them.

Simultaneously, and for identical health and safety reasons, the CCS suspended adjustment in situ and replaced it with remote or video adjustment. Using this system, the CCS has continued to handle claims processes that had already been begun by adjustment on location prior to the declaration of the state of emergency and has started handling work on a new flood (on the coastal zone of the province of Castellón and which occurred between 31 March and 1 April) which has triggered 2,000 claims that are being remotely adjusted and handled in their entirety.

After much suffering and sacrifice by many sections of the society in which we live, most particularly, the healthcare sector, it is making good progress towards overcoming the pandemic and along the road to recovering the levels of economic activity which we saw before. As ever, the CCS wants to be a part of the solutions that help society negotiate this awkward and uncertain path.

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