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DEFINITION OF THE 4 TOPOGRAPHICAL AREAS OF THE MEDITERRANEAN MOST COMMONLY AFFECTED BY FLASH FLOOD

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Executive summary

This deliverable is part of the Activity 1.1 entitled "Definition and description of the topographical areas most affected by flash floods" from *WP1 - DESIGNING LOCALL4FLOOD integrated multi-stakeholder governance model – IMGM*. This document aims to describe the specific risks and challenges associated with flash floods in the most affected topographical areas among Mediterranean countries: Urban areas, Industrial areas, Natural and Rural areas, and Coastal areas. Based on this description, this report also identifies the circumstances in each topographical area in which the implementation of the Integrated Multi-Stakeholder Governance Model (IMGM), grounded on prevention, adaptation, and mitigation actions and developed by LocAll4Flood project, can significantly reduce the identified risks associated with flash floods and which of the tools developed would be more suitable to be applied and effective in each topographical area to minimize these risks. Overall, this deliverable will serve as a key reference document, providing all participating partners of LocAll4Flood, but also policy makers and flood managers, a shared understanding of the definition and characterization of flash floods, the risks associated to them in different topographical areas, the main challenges to face these risks, and the suitableness of the tools provided by the Locall4Flood project to address them.

This document is presented in the following order. Section 2 introduces the rationale behind the work being done in this report. Section 3 elaborates on most common risks associated with flash-flood events in the different topographical areas. Section 4 highlights the main challenges in facing the risks associated with flash-flood events. In Section 5, the usefulness of the LocAll4flood IMGM in each of the topographical areas is described. Finally, Section 6 gathers the main takeaways from this report. The key takeaways are as follows:

- Designing tailored solutions for flood management and avoiding one-size-fits-all approach.
- Developing and implementing an integrated approach to flood management that encompasses prevention, adaptation, and mitigation.
- Including multi-stakeholder engagement and collaboration in the design, testing, and implementation of solutions in flood management

1. Introduction

Floods are the most common and among the most costly natural disasters in Europe, and they are becoming more frequent due to climate change[1]. Indeed, according to the European Environment Agency (EEA), heavy rainstorms are projected to become more common and more intense because of higher temperatures, with flash floods expected to become more frequent across Europe, especially around the Mediterranean[2],[3]. Floods can cause injury, loss of life, considerable economic costs, damage to the environment and heritage, and the resettlement of people.

For example, the data collected in the Mediterranean Flood Fatality Database[4] (FFEM-DB) reported around 280 fatal floods in the last 40 years (1980-2020) causing 793 human losses in six of the sensitive Mediterranean regions where the solutions developed within LocAll4Flood project will be tested (i.e., Catalonia, Balearic Islands, Malta, Bulgaria, South of Italy, and Greece). Apart from posing a high danger to humans, individual flood events can cause economic losses in the range of several billion euros. According to the European Environmental Agency, climate-related extremes in Europe amounted to an estimated EUR 650 billion between 1980 and 2022, and hydrological hazards, specifically floods, account for almost 43% (279.5 billion)[5].

In response to the rising incidence of flooding, the EU adopted the Floods Directive (Directive 2007/60/EC) in 2007 to reduce and manage the risks that floods pose to human health, the environment, cultural heritage, and economic activity across Europe[6]. The main aim of this directive is to coordinate flood prevention, protection,

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[1] European Environment Agency (EEA). 2024. Responding to climate change impacts on human health in Europe: focus on floods, droughts and water quality. EEA Report 3/2024. 2024.

[2] Ali, E., W. Cramer, J. Carnicer, E. Georgopoulou, N.J.M. Hilmi, G. Le Cozannet, and P. Lionello, 2022: Cross-Chapter Paper 4: Mediterranean Region. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 2233–2272. doi:10.1017/9781009325844.021.

[3] Moatti, J. P., & Thiébault, S. (Eds.). 2018. The Mediterranean region under climate change: A scientific update. IRD éditions.

[4] Petrucci, O., Aceto, L., Bianchi, C., Brázdil, R., Diakakis, M., et. al. 2022. FFEM-DB "Database of Flood Fatalities from the Euro- Mediterranean region". Version 3. 4TU.ResearchData. Dataset. https://doi.org/10.4121/14754999.v3

[5] European Environment Agency. 2023. Economic losses from weather- and climate-related extremes in Europe.

[6] Council of the European Communities, 2007. Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the Assessment and Management of Flood Risks.

and preparedness within and between Member States, at the river basin level. Under the Floods Directive, all EU countries are required to identify all sensitive areas where significant floods could take place, map the flood extent and assets, and assess the respective risks to humans and infrastructures in these areas, to take adequate and coordinated measures aimed at reducing this flood- associated risk. Specifically, the main requirements of the Directive are:

- Member States must complete preliminary flood risk assessments to identify areas of potential flood risk by 2011, to be revised every 6 years thereafter.
- Member States must develop flood hazard maps by 2013 and update them every 6 years thereafter.
- Member States must create flood risk management plans (focusing on flood prevention, protection, and preparedness) by 2015, and every 6 years thereafter.

Therefore, the Floods Directive establishes a common framework for flood risk management and foresees 6-year cycles (2010-2015, 2016-2021, 2022-2027 and so on) aiming at reducing the risk of flood damage in Europe.

Since the introduction of the Floods Directive in 2007, progress in flood management in Europe has been made in many aspects[7]. In particular, the Floods Directive was pivotal in documenting and assessing flood risks, and Member States have begun implementing Flood Risk Management Plans to address them. However, extending the concept of flood risk management to flash floods, which tend to be more severe in the Mediterranean, still faces several challenges.

A flash flood is a flood of short duration with a relatively high peak discharge in which the time interval between the observable causative event and the flood is less than four to six hours[8]. Flash floods are driven by a combination of natural and anthropogenic factors: a) heavy rainfall (intense precipitation volumes within a short time); b) unfavorable topography (steep terrains and highly inclined valleys, channel routes, ground impermeability, etc.); c) saturated soil (unable to absorb rainwater); loss of vegetation cover (deforestation, deplantation, etc.); d) urbanization (development of built environments increase terrain imperviousness); e) failure of dams and levees; f) upstream ice jams in rivers; g) rapid snowmelt; h) human interventions in natural settings (overdevelopment, mining, and land- altering activities). Flash floods indeed pose unique challenges in managing flood hazards. Between 1870 and 2020, close to 49% of floods causing significant socio-economic impacts across Europe were attributed to short yet intense rainfall events[1].

[7] Current Practice in Flood Risk Management in the European Union. European Commission, 2021.

[8] WMO, 2006. Technical Regulations. Volume III: Hydrology, WMO-No. 49. World Meteorological Organization (WMO).

Flash floods are spatio-temporal localized flood events usually occurring in small, steep basins. As a result, flash floods can rapidly generate high-velocity water flows with enough force to cause significant damage to property and endanger lives. The swift onset and powerful currents make it challenging for individuals to react or evacuate in time, increasing the risk of casualties and destruction. In addition, the small spatial and temporal scales of flash floods make these events particularly difficult to predict[9] using conventional methods. Since commonly only main rivers are monitored, these small basins often lack gauging stations, and warning alerts relying on river gauge trends and weather forecasts underestimate the risk of flooding. The sudden onset and rapid rise of water levels associated with flash floods often leave little time for warning and preparation, making them particularly difficult to manage. These characteristics make flash floods extremely hazardous events, which pose important challenges to emergency managers, public administrations, and societies.

Flooding can often affect differently at a very local scale, and local, focused information is necessary to allow an effective response and reduce vulnerability. As the Floods Directive states[6] "in each river basin district or unit of management the flood risks and need for further action — such as the evaluation of flood mitigation potential — should be assessed". Therefore, it is necessary to identify the specific risks associated with floods at the catchment level to determine where action is needed. In Mediterranean river basins, different topographical areas, such as rural, urban, industrial, and coastal, are typically crossed by the same river course, and each is characterized by varying types of risks associated with flash floods events. The identification and understanding of the specific risks associated with flash floods in different topographical areas within Mediterranean river basins are crucial for the informed and effective implementation of actions tailored to each specific case for flash- flood risk management. In fact, to improve the effectiveness of prevention, adaptation and mitigation actions aimed at reducing vulnerability and improving the response capacity of concerned stakeholders and the resilience of affected communities, it is essential: i) to identify specific risks in the sensitive reaches; and ii) to understand which actions could be more effective to minimize the specific risks identified.

In essence, the more accurately we can identify and understand the risks associated with flash floods in different topographical areas, the better equipped we are to mitigate those risks and build more resilient communities. It is a foundational step towards creating safer and more sustainable environments for everyone.

[9] Borga, M., Anagnostou, E. N., Blöschl, G., & Creutin, J. D. (2011). Flash flood forecasting, warning, and risk management: the HYDRATE project. Environmental Science & Policy, 14(7), 834-844.

Within this framework, this report aims to describe the specific risks and challenges associated with flash floods in the most affected topographical areas among Mediterranean countries: Urban areas, Industrial areas, Natural and Rural areas, and Coastal areas. Based on this description, this report also identifies the circumstances in each topographical area in which the implementation of the Integrated Multi-Stakeholder Governance Model (IMGM), grounded on prevention, adaptation, and mitigation actions and developed by LocAll4Flood, can significantly reduce the identified risks associated with flash floods and which of the tools developed would be more suitable to be applied and effective in each topographical area to minimize these risks.

2. Identification of the most common risks associated with flash-flood events in the different topographical areas

Considering that most of the catchments sensitive to flash-flood events are normally crossing lands of different topographical areas, the most appropriate way to approach the reduction of the risks associated with such catastrophic events is to identify the specific hazards posed by flash floods, depending on the dominant land use and the topographical area in which the sensitive reaches of the catchment area is potentially affected. Each topographical area has its own unique characteristics and vulnerabilities. By understanding these specifics, authorities can tailor their approaches to disaster management, implementing solutions that are most relevant and effective for each area. However, the hazard is only one part of the definition of risk. The vulnerability of the affected system – i.e., urban areas, industrial areas, natural/rural areas – is part of the risk equation and affects the intensity and scale of the flash-flood impacts.

To this end, this deliverable aims to first recognize specific risks associated with flash-flood events in different topographical areas and then suggest which types of solutions can be more effective in reducing the respective risks associated, among those included in the LocAll4Flood IMGM and grounded on the three pillars: prevention, adaptation, and mitigation.

Identifying common risks associated with flash-flood events in different topographical areas requires an understanding of the specific characteristics and vulnerabilities of each area. Here's a breakdown of the risks associated with flash floods in urban, industrial, rural/natural, and coastal areas:

Urban Areas:

- Stormwater Drainage System Overload: Urban areas often have extensive impermeable surfaces like roads, pavements, and buildings (e.g., pipe-

drained impervious terraces), leading to rapid surface runoff during heavy rainfall. This causes overflow of stormwater drainage systems and provokes inundation not only related to river catchments, making it more difficult to forecast.

- Sewerage Network Overload: Flash floods can overwhelm, especially the old-school combined (urban and stormwater) sewerage network systems, possibly leading to health risk issues due to the dispersion of pollutants, contaminants, and pathogens. The conditions of the drainage and sewage system affect its capability to react in case of a flash flood. Therefore, assessing the vulnerability of this system should account for its different intrinsic characteristic. Similar to the previous point, the sewage vulnerability is affected by the network's topology and the state of maintenance.
- Infrastructure Damage: Flash floods can damage roads and associated infrastructure (streetlights, signs, bridges, tunnels, culverts, etc.), public transportation systems (railroads, subways, etc.), recreational and other open areas (parks and green spaces), and utilities, leading to disruptions in transportation, communication, and other essential services (e.g., first-level emergency response systems, search-and- rescue efforts, etc.). In this case, the vulnerability depends on the location of these infrastructures – i.e., how close they are to potential sources of flash floods – and the level of protection against the flood episodes. Also, it is important to note that there are numerous river barriers, including dams and weirs, across Europe, which can be susceptible to damage or destruction during extreme flood events.
- Property Damage and Loss: Buildings and personal property (cars, motor/bicycles, and other moveable items) are at risk of damage or destruction during flash floods, leading to financial losses for residents and businesses. Similar to the previous point, the distance from the sources of flash floods and the presence of protection systems affects the property-related risk.
- Health and Safety: Urban flash floods pose risks to human safety, including casualties from drowning (particularly in cities and urbanized settings with tunnels and unstable structures for crossing rivers), injuries from drifting in floodwater and debris entrainment, and electrocution from exposed electrical equipment. Also, urban flash floods pose health risks of water-borne diseases from untreated wastewater.
- Runoff-induced pollution: Urban flash floods also threaten with pollution by transporting suspended solids (increased turbidity), plastic and other debris (metallic, wooden etc.) and urban litter towards accumulating water bodies (coastal marine areas, ponds, lakes, lagoons, etc.). The proximity of potential

pollutant sites to the sources of the flash flood, and the lack of protection measures, affect the vulnerability level.

- Socio-economic impacts: Flood events trigger significant socio-economic and psychological impacts, leading to displacement, property damage, and loss of lives. These events foster financial strain, disrupt daily life, and cause profound grief and trauma within affected communities. This impact is especially important in urban, densely populated areas affected by flash floods. Several scholars have dealt with the identification of socio-economic vulnerability. Several elements were mentioned as influencing this vulnerability, such as demographic characteristics, socio- economic status, health, coping capacity, and risk perception.

Industrial Areas:

- Chemical Spills and Contamination: Flash floods can inundate industrial sites, causing spills of hazardous materials and pollutants, leading to environmental contamination and health risks. Chemical contaminants transported by floodwater can have long-term environmental consequences, affecting groundwater reservoirs, surface water bodies, nearby ecosystems, and habitats.
- Infrastructure damages: Industrial facilities may suffer damage to buildings, machinery, and utilities, disrupting operations and posing risks to workers.
- Production Loss and Socio-Economic Impact: Interruptions to industrial processes due to flood damage can result in downtime of services/goods' supply chain and loss of production, revenue, and employment in the affected area.
- Fire and Explosions: Floodwaters can damage electrical systems and trigger fires or explosions in industrial facilities, exacerbating the risks to personnel and nearby communities.
- Human safety: all the risks mentioned in industrial topographical areas are directly or indirectly related to risks for human safety, especially workers and employees in industry.

In general, vulnerability of the industrial sites is mainly related to the specific location of the sites and the presence of protection measures.

Rural/Natural Areas:

- Erosion and Sedimentation: Flash floods in rural and natural areas can cause erosion of soil, loss of vegetation, and sedimentation in water bodies, affecting ecosystem health and water quality in surface water bodies. The vulnerability to erosion and sedimentation of natural areas is greatly influenced by the condition of the riverbed and riverbanks, as well as the presence of barriers such as dams and weirs. These structures can alter the

natural flow of rivers, leading to changes in sediment transport patterns and erosion rates. Additionally, poorly maintained, or compromised barriers can exacerbate erosion and sedimentation issues by disrupting the flow of water and sediment. Therefore, the condition of both natural and man-made features along river systems plays a crucial role in determining the susceptibility of areas to erosion and sedimentation. Moreover, soil quality, soil coverage and slopes affect the soil erosion vulnerability.

- Damage to Agricultural lands: Farmlands and crops are vulnerable to inundation and soil erosion during flash floods, leading to farm infrastructure and crop loss, and reduced agricultural productivity (downtime of primary sector).
- Livestock and Animal farming: Flash floods can impact livestock and animal farming. The sudden influx of water can destroy barns and grazing areas, contaminate water sources, and spread disease among animals.
- Wildlife at risk: Flash floods pose risks to wildlife, with potential loss of animals and habitat destruction, breeding grounds disruption or displacement of wildlife, which affect ecological balance and local biodiversity.
- Isolation and Access issues: Rural communities may become isolated due to damage to roads and bridges, hindering access to essential services and emergency assistance, such as education and healthcare.
- Damage to Cultural Heritage: Rural areas often contain most of the historical sites and cultural landmarks (particularly in the Mediterranean) that are vulnerable to flood damage, threatening their preservation and heritage value.
- Tourism and Recreational activities: The risk of flash floods poses significant safety concerns and disruptions to tourism and recreational activities in flood-prone areas. Rapidly rising waters can endanger tourists and participants engaged in outdoor pursuits, leading to cancellations, evacuations, and potential damage to infrastructure, as well as injury or loss of life.

The location of the agricultural lands, livestock sites, cultural heritage sites and touristic activities, and the availability of protection measures affect the vulnerability of these elements.

Coastal Areas:

- Storm Surge and Coastal inundation: Flash floods in coastal areas can be exacerbated by storm surges, leading to rapid inundation (compound flooding) of low-lying areas and coastal communities.
- Beach Erosion and Coastal Infrastructure Damage: Flash floods can accelerate erosion of beaches (e.g., coastline retreat and dune breaching)

and damage coastal infrastructure such as seawalls, promenades and recreational pavements, piers, port structures, and buildings located along the coastline. These can cause disruption of maritime activities and port downtime affecting marine transportation, commerce, fisheries, shipping, etc.

- Saltwater Intrusion: Coastal flash floods can cause infiltration of saltwater into surface freshwater and groundwater systems, affecting drinking water supplies, pumping infrastructure (wells, etc.), irrigation for agriculture, littoral farmlands, and ecosystems.
- Impact on Tourism and Recreation: Coastal flash floods can disrupt tourism and recreational activities, impacting local economies that rely on these industries.
- Chemical spills and contamination: Waste displacement from inland through the rivers to the sea and the beaches can affect the water quality and ecological status of coastal ecosystems. Urban flash floods can threaten the coastal waters with pollution by transporting turbid water masses, sediments, debris, contaminants, nutrient-rich waters, and urban litter to the coastal ocean. Additionally, wastewater treatment plants often release untreated water during heavy rain events due to capacity overload, especially in urban areas without adequate stormwater management infrastructures.
- Port and commercial activities: Coastal flash flood can impact port activities and commercial activities connected to the port area.
- Loss of Coastal Habitats: Flash floods can degrade coastal habitats such as wetlands, mangroves, etc., diminishing their ability to provide ecosystem services and protect against coastal hazards.
- Impact on Fisheries and Aquaculture: Coastal flash floods can further impact the coastal fishing and mariculture activities and communities due to the abovementioned identified risks.

The vulnerability of coastal areas to flash floods depends on the natural elements, as well as the socio-economic and institutional characteristics. Concerning the natural elements, low- lying coastal areas are particularly prone to flooding due to their proximity to sea level. Coastal plains and river deltas, with their flat terrain, can rapidly accumulate water, increasing the risk of flooding. Additionally, meteorological patterns, precipitation trends, sea level rise, and hydrology are key factors in this system. Regarding the socio-economic elements, urbanization and development in coastal areas reduce natural soil absorption and increase runoff. Poorly planned infrastructure, inadequate drainage systems, and deforestation further exacerbate flood risks. For what concerns the institutional part of the coastal

system, the decisions made by institutions significantly influence the allocation and management of resources in hazard mitigation processes.

3. Main challenges in facing the risks associated with flash floods events

Flash floods represent a unique subset of flood hazards, characterized by their rapid onset, often with minimal or no advance warning, resulting in fast-moving and rapidly rising waters with significant destructive force capable of causing infrastructure damage and loss of life. This extremely sudden onset is the main driver behind the devastating potential of flash floods, as it leaves little time to coordinate flood response measures (e.g., evacuations or installations of non-permanent flood protection systems). In addition, in the Mediterranean Basin, flash floods typically occur in small to medium-sized catchments lacking gauging stations, making them challenging to predict and monitor. Moreover, due to the high-density population in the Mediterranean Basin, they frequently affect densely populated areas with a high presence of housing, services, and commercial activities, exacerbating the risks posed by these sudden and intense flooding events.
Because of all the reasons mentioned above, flash floods are extremely hazardous events that pose particular challenges to the key receptors identified in the introduction of this report (i.e., cultural heritage, the environment, economic activity, and human health), as well as to key stakeholders such as emergency managers, public administrations and societies. Here, we outline the main challenges in facing the risks associated with flash flood events in the Mediterranean region:

- **Prediction and monitoring**: Flash floods present a significant challenge for observation and prediction due to their rapid onset and localized nature. Conventional rain and discharge measurement networks often lack the spatial and temporal resolution needed to capture these events accurately. This limitation underscores the importance of developing innovative monitoring techniques and predictive models tailored to the unique characteristics of flash floods[2] to provide early warnings and communicate developing situations during ongoing floods. Also, it is important to integrate flash flood forecasting and warning into risk management strategies. Early warning systems can help extend the anticipation horizon of flash floods and are considered by the European Environmental Agency[10] as the most effective measure to reduce their negative impacts. However, these systems are often not available for small catchments and non-permanent streams,

[10] EEA, 2010. Mapping the impacts of recent natural disasters and technological accidents in Europe: an Overwiev of the last decade, EEA Environmental issue report – No. 35. https://doi.org/10.2800/62638

making it urgent to provide such tools to emergency managers. One reason for this limitation is the significant challenge of forecasting accurately for small catchments due to their size. Their small size makes it difficult to determine whether heavy rainfall will occur in a specific catchment or its neighbouring one due to the lack of precision in spatial resolution. In this context, it is important to develop reliable warning systems, grounded in robust and finely tuned forecasting and hydrometeorological models, to be delivered to first responders to provide relevant support to the fast-decision-making process.

- **Preparedness and response management**: Short available time for hazard anticipation is challenging and requires accurate preparedness and response management by organisations and people. In addition, because flood risk touches many aspects of society, flood management often involve many different organisations, stakeholders, and the public. Working in partnership aims to improve effectiveness, clarity for public and stakeholders, and can help achieve the expected outcomes. An active role of the general public is beneficial because it can lead to better measures that fit the local setting and are more acceptable. Moreover, the resulting awareness can also reduce flood vulnerability. However, developing partnerships and establishing a collaborative decision-making network to face flash-floods[1] can be challenging. Preparedness and response management are often considered as collaborative decision-making processes. That is, the effectiveness of these measures requires the coordinated involvement of experts and organisation from different sectors and fields. Nowadays, the response to crises becomes an emerging, large-scale, socio-technical system of individuals, groups, organisations, and jurisdictions that need to coordinate their actions for delivering effective operations. No single entity has complete control of these multi-scale, distributed, highly interactive networks, or the ability to evaluate, monitor and manage emergencies in real time. Therefore, we argue that a collaborative emergency management requires tools and methodologies capable of creating a decision-making environment in which parties are fully aware of their roles and the roles of the others in the interaction space, creating an effective and collaborative decision-making environment.
- **Communication and engagement**: Communicating flood risk can present a challenge where multiple actors, with varying degrees of understanding, need to interpret or apply the information. In addition, mapping and communicating flood risk from various sources for different scenarios and risk profiles can be also challenging. Communication of flood risk at all levels needs to be improved so that there is a better understanding across a range

of stakeholders, enabling the necessary actions to be taken for flood management. In addition, effective engagement with the public is important to understand and incorporate local issues, as well as to achieve local acceptance and participation. However, public engagement has proved more challenging compared to engagement with professional partners[1]. This is mainly because, in most cases, the management of flash flood risk is mainly perceived as a technical task rather than a more general duty in which decision-makers, first responders and citizens need to be involved to minimize the risk associated with these events.

- **Nature-Based Solutions:** For several years now, European policy has been promoting nature-based solutions (NBS) with the aim to tackling environmental challenges while achieving a greener economy and sustainable development. In the field of flood management, previous experiences have demonstrated that such measures have strong potential to contribute towards meeting the objectives of the Floods Directive, and EU Strategy on Adaptation to Climate Change. However, flood risk management plans rarely consider NBS[11]. Despite the reasons for not choosing NBS for flood management being largely unexplored, some research states that multi-stakeholder collaboration and co- creation of knowledge are important prerequisites for a shared understanding of problems, developing actionable knowledge and adapting NBS to site-specific societal challenges[12]. The limited implementation of NBS for flash-flood risk reduction is also due to knowledge barriers within the organisations devoted to NBS design and implementation, such as municipalities and regional authorities. Technical knowledge for designing grey infrastructures is rather consolidated. Technicians possessing this knowledge hold prestigious positions within their organisation. NBS are rather new and adopting them would require changing the knowledge (power) hierarchy within the organisation.
- **Integrated approach**: An integrated approach to managing flash flood is essential but can sometimes be challenging. It is needed to combine bottom-up and top-down approaches, including all actors involve (directly and indirectly) in flood management, but also integrating various management strategies including prevention, adaptation, and mitigation actions. Risk

[11] Nature-Based Solutions: State of the Art in EU-funded Projects European Commission. EU Comission, 2020.

[12] Wickenberg, B., McCormick, K., & Olsson, J. A. (2021). Advancing the implementation of nature-based solutions in cities: A review of frameworks. Environmental science & policy, 125, 44-53.

management should be based on a fully integrated approach which recognizes the specificities of flash floods[2].

4. Identification of the usefulness of LocAll4Flood - IMGM in each of the topographical areas

LocAll4Flood project will develop and test an innovative Integrated Multi-stakeholder Governance Model (IMGM) to manage flash floods to reduce the risk associated with these extremely hazardous events in the Mediterranean region. This governance model (IMGM) will be designed for four different topographical areas (Urban, Industrial, Rural/Natural, Coastal) and tested in nine pilot catchments located in six regions particularly sensitive to flash floods in Greece, Italy, Bulgaria, Malta, and Spain (Catalonia and Balearic Islands).

This integrative approach is grounded on three conceptual pillars: prevention, adaptation, and mitigation, which are combined in an integrated flood management strategy that consider both land and water resources in small catchments.

Based on the previous description of the main risks on each area and the main challenges to face them, this section aims to identify the circumstances in which the implementation of the LocAll4flood – IMGM can mitigate the identified risks associated with flash floods and determine which of the tools developed (prevention, mitigation, adaptation) would be more suitable to apply in each area to overcome the identified challenges and reduce these risks.

Subsequently, we present the tools included in the LocAll4flood – IMGM model, the main challenges addressed by them and the topographical areas where their implementation could be more effective in reducing the identified risks caused by flash floods:

PREVENTION - Improved forecasting tools & early-warning systems: Prevention actions will focus on the development of specific hydro-meteorological forecasting tools and early warning systems (EWS).

Challenges addressed: Prediction and monitoring.

Topographical area: Improved forecasting tools and early-warning systems are essential in urban, industrial, and coastal areas. Implementing robust forecasting mechanisms enables timely alerts and proactive measures, which are crucial for minimizing risks, safeguarding lives, and protecting critical infrastructure in these highly populated and economically significant areas.

ADAPTATION - Implement participatory actions to raise awareness: educational and awareness-raising activities will be executed as a tool to improve the response capacity of citizens and authorities to these events. Participatory education actions will be carried out to raise the social awareness about the risks associated with flash

flood events and promote a behavioral adaptation of citizens in response to warning messages issued by emergency management authorities.

Challenges addressed: Preparedness and response management; Communication and engagement.

Topographical area: Participatory actions aimed at raising awareness about flash- flood risks are particularly crucial in densely populated urban areas. Through educational campaigns, workshops, and community engagement initiatives, residents can be informed about the potential dangers of flash floods and empowered to take proactive measures to mitigate these risks. By fostering social awareness and promoting behavioral adaptation, urban areas can enhance resilience and ensure the safety of their inhabitants in the face of flash-flood events.

MITIGATION - Lay the foundations for the implementation of NBS: Nature-based solutions (NBS) will be proposed as a tool able to reduce the negative effects of flash-flood events bringing together multidimensional benefits that integrate technical, economic, governance, regulatory and social innovation.

- Challenges addressed: Nature-Based Solutions, Integrated approach.
- Topographical area: The implementation of NBS presents a promising approach to mitigate flash-flood risks, particularly in rural or natural areas. These regions often have more available land for NBS interventions, such as floodplain restoration or creation of wetlands to reduce flood risks. Additionally, rural and natural areas typically have fewer existing urban structures, making it easier to integrate NBS without significant modifications to infrastructure.

5. Conclusions and key takeaways

This report provided a comprehensive overview of the specific risks and challenges posed by flash-flood events in various topographical contexts across Mediterranean countries. The LocAll4Flood project aligns with the following key takeaways from this report, that will be used as criteria for selecting the pilot sites for the Locall4flood project on each topographical area:

- Takeaway #1 – Designing tailored solutions and avoiding one-size-fits-all approach. There is a need for solutions specifically adapted to the topographical (as well as social and economic) contexts of each local region. This means creating flash- flood management strategies that consider the unique conditions of each affected local area. Ensuring that interventions are context-specific and therefore more likely to be effective is crucial, which is why LocAll4Flood stresses the importance of identifying the particularities of each topographical area and catchment.
- Takeaway #2 – Developing and implementing an integrated three-pronged approach to flood management. This involves bringing together solutions that on prevention, adaptation, and mitigation. By addressing all three aspects, LocAll4Fllod project ensures a comprehensive strategy to manage and reduce flood risks and impacts.
- Takeaway #3 - Including a multi-stakeholder engagement and collaboration into the design, testing and implementation of solutions. Involving multiple stakeholders leads to more comprehensive and effective solutions. LocAll4Flood emphasizes the importance of collaborative efforts among all actors involves, such as government agencies, private sectors entities, non-profit, and the public to create robust and more accepted and widely known flood management strategies.