ADDRESSING RIVERINE FLOODING WITH NATURE-BASED SOLUTIONS IN THE THESSALY REGION, GREECE

PRE-FEASIBILITY STUDY

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List of Terms and Abbreviations

Terms
The Study The present pre-feasibility study for the Thessaly Region.
The Project Team Global Infrastructure Basel Foundation (GIB), World Wildlife Fund Greece (WWF GR), Icatalist (ICA), The Nature Conservancy (TNC), National Technical University of Athens (NTUA) and Swiss Re.

Abbreviations
APSFR Areas of Potential Significant Flood Risk
CAP Common Agriculture Policy
CLC Corine Land Cover
EC European Commission
EGY/RIS Special Water Secretariat of the Ministry of Environment and Energy
EIB European Investment Bank
FH Flood Hydrograph
FRMP Flood Risk Management Plan
FS Feasibility Study
HEM-HMS Hydrological Modelling System
GIIP Good international industry practice
IUCN International Union for Conservation of Nature
MRDF Ministry of Rural Development and Food
NbS Nature-based Solutions
NAS National Adaptation Strategy
NCFF Natural Capital Financing Facility
NCL Nature for Catchments Launchramp
NWRM Natural Water Retention Measures
OECD Organisation for Economic Co-operation and Development
PP Pilot Project
RBD River Basin District
RBMP River Basin Management Plan
SCI Sites of Community Importance
SDG Sustainable Development Goal
SPA Special Protection Areas
WFD Water Framework Directive
PREFACE

This study has been prepared by Global Infrastructure Basel Foundation (GIB) and World Wildlife Fund Greece (WWF Greece) as part of the Nature for Catchments Launchramp (NCL) and the project NbS: Engaging key stakeholders & mapping of priority areas. Nature for Catchments Launchramp has been funded by the Mava Foundation and the European Investment Bank (EIB) while NbS: Engaging key stakeholders & mapping of priority areas has been funded by WWF Netherlands through the Living European Rivers (LER) Initiative. Other institutions involved in the study were Icatalist (ICA), The Nature Conservancy (TNC), National Technical University of Athens (NTUA) and Swiss Re. The research was carried out between March 2021 and April 2022 by a team including the following researchers:

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Disclaimer

The views outlined in this study are based on research conducted by the project team and do not reflect the views of the European Investment Bank or the MAVA Foundation. The views, opinions and recommendations in the study are based on assumptions made by the project consortium when undertaking services and preparing the study, as detailed below. The consortium expressly disclaims responsibility for any error in, or omission from, this study arising from or in connection with any of the assumptions being incorrect. The recommendations made as part of the project have been considered and evaluated by the project team without full assurance as to their validity (i.e., which falls outside the scope of this assessment). The project recommendations will be validated in future technical studies (e.g., Feasibility Study).
EXECUTIVE SUMMARY

This document presents the outcomes of a pre-feasibility study on the use of a range of Nature-based Solutions (NbS) for flood risk reduction, water quality and quantity improvements, and other co-benefits in the western part of the region of Thessaly in Greece.

“Flood affects more people around the world than any other peril. Losses from flood have been on an upward trend globally and at a significantly faster pace than global GDP” (Sigma, 1/2022, p.2). In Europe, river floods are among the most damaging extreme climate events and under a high-emissions scenario; climate change could triple the direct damages from river floods during the 21st century in the absence of additional adaptation measures (EEA, 2021).

The region of Thessaly in Greece is extremely vulnerable to floods, which frequently result in several casualties and significant economic losses. Moreover, the frequency and severity of flood events has increased in the past years due to climate change, economic development and landscape changes. The latest major flood event (known as the “Iannos Medicane”, in September 2020), is considered one of the most disruptive events ever to have hit the region, causing estimated economic losses totalling between EUR 0.5 – 1 billion.

The region is constantly challenged by severe flood events, despite the fact it has already implemented a number of flood protection measures, including dams and dykes. These measures are also known as “grey” infrastructure: artificially constructed systems, built from materials such as steel and concrete to deliver a specific service. Usually, grey infrastructure is resource-intensive, involves substantial operation and maintenance costs and often entails environmental impacts. Furthermore, it often relies on artificial structures and systems that are increasingly being recognised as less adaptable to changing operating conditions.

On the other hand, this study investigates the use of Nature-based Solutions (NbS) to respond to socio-environmental challenges such as water security, food security, human health and disaster risk reduction. NbS is an innovative concept that takes the form of natural systems, as opposed to conventional “grey” infrastructure solutions. NbS are primarily composed of flora, fauna, natural materials (e.g., rocks, soil and sand) and water and provide infrastructure-like services. Depending on context and needs, NbS can complement, augment or replace conventionally-built infrastructure. The study recognises the benefits of creating a portfolio of mixed natural-grey solutions, and focuses on assessing NbS which could be implemented either as stand-alone projects, or as green measures to complement existing grey structures.

According to the UN, there is a critical need to triple the annual investments in NbS globally by 2030. To accelerate this process, the project team has developed a Nature for Catchments Launchramp methodology that is designed to support large investors, primarily development finance institutions (DFIs), in sourcing a pipeline of bankable projects and to enable capital seekers (e.g. public decision-makers such as regions and cities) to better access catalytic capital to develop impactful infrastructure projects and thus contribute to the increase of annual investment into nature. The present study demonstrates the approach in the Thessaly region in Greece. However, its real value derives from its scalability potential: this approach can be applied in other climate-vulnerable regions, in Europe and beyond, to assist financing institutions such as the European

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1 UN, 2021
**Investment Bank (EIB)** to originate and finance **climate-positive projects** at the needed scale that contribute to a number of **Sustainable Development Goals (SDGs)**.

The above-mentioned methodology allowed the **project team to undertake a context and situation analysis** (including policy, governance, finance, and site-specific considerations) for the study area, and to identify a potential set of **Nature-based Solutions (NbS)** that could reduce the risk exposure of the local communities and economy to the impact of floods. **Relevant policies, laws and plans have been explored**, such as the EU Water Framework Directive and the EU Floods Directive, as well as conservation directives relevant to the Greek context.

Through stakeholder engagement with ministries, cities, and academic and financial institutions, **the study confirms the viability to proceed with other technical studies** (e.g. feasibility study) from both a technical and a political standpoint. Technically, the project team identified existing hydrological studies that indicate the viability and opportunity to use NbS such as natural water retention ponds, wetlands, flood plains, as well as urban greening strategies and upgrades to agriculture practices to effectively reduce flood risk. From a political standpoint, the project team have learnt that there is very strong political will (at all levels) to reduce flood risk. However, current plans focus heavily on grey solutions (including the potential creation of several new dams in the target water catchment). This stresses the importance of information exchange, political commitment and further technical studies as defined in the "Next steps" chapter.

The proposed NbS interventions outlined in this study have been pre-selected based on their ability to address **water security challenges** experienced at the local scale, as well as other challenges such as the over-exploitation of groundwater aquifers, and the loss of biodiversity and native habitat. A set of NbS interventions has been proposed for 8 sub-basins (out of 12) within the Pineios river catchment in the Thessaly region, based on its value to the region. These interventions are outlined in Chapter 4 (Proposed Nature-based Solutions interventions), which also shows the number of potential areas that have been identified as suitable for the implementation of each NbS. Expected benefits of the proposed NbS interventions and their magnitude are also provided in this chapter. **The proposed NbS interventions are an estimate** at this stage. A thorough evaluation of various interventions should be carried out at the feasibility stage, giving **special attention to local stakeholder consultation, particularly to farmers and local municipalities**. This will allow for better informed decisions on the most suitable, socially acceptable and effective options to consider.

The identified NbS interventions have the ability address flood events of different magnitudes (e.g. 50-, 100- 500- year return period) depending on the specific local need. Obviously, this would have implications for the overall number of the interventions and their type, design and scale. To provide an example, the project team conducted a hydrological and hydraulic analysis for one of the eight studied river sub-basins - Ano Pineios - to calculate the needed **retention capacity of the NbS interventions to mitigate a flood event with a return period of 50 years**. It was found that approximately 17 million m³ of runoff volume would need to be retained by the upstream NbS (e.g. ponds, wetlands, forests or floodplains). This volume could be distributed into multiple NbS, located evenly at the upper parts of the sub-basin, before the river enters municipalities and areas where critical infrastructure is situated (e.g. roads, bridges, electric transmission lines). The flood mitigation effect would be achieved by lowering the maximum flow and increasing the lag time. The full analysis can be found in Annex 4.

As the ultimate objective of this work is the implementation of a **pilot project**, the study also provides suggestions on **next steps** in a “**roadmap**”. For example, it calls for conducting **technical studies** (hydrological/hydraulic), designing a **monitoring and evaluation programme** to measure the performance of implemented interventions, and designing a **Regional NbS Implementation Programme** – a long-term strategy to enable the region to respond to a number of future challenges. It also suggests establishing a **steering committee** that would oversee the work to be done in the next stages (e.g. feasibility, design, execution) and deploying **support tools** (e.g. NbS and infrastructure standards) to ensure the best possible design and execution of projects, following Good International
Industry Practice (GIIP). For example, the project team suggests using the IUCN Global Standard for NbS to integrate key criteria in the implementation process and hence to avoid potential “green washing”.

In summary, the study supports the claim that the unwanted impacts of riverine flooding in the region of Thessaly in Greece can be effectively addressed with Nature-based Solutions, provided there is a strong political will to shift national/regional investments from grey infrastructure to Nature-based Solutions (NbS). Allowing NbS to complement, augment or replace conventional grey structures, where possible, would increase regional resilience and create additional benefits for the local communities.
AMBITION OF THE STUDY
1. AMBITION OF THE STUDY

Summary box

- The ambition of the study is to conduct a preliminary assessment of the feasibility of Nature-based Solutions, and their ability to deliver critical services including flood risk reduction, and improvement of water availability (i.e., surface water & ground water).
- The portfolio of solutions could include a series of mixed natural-grey solutions, not consisting exclusively of natural components.
- The proposed solutions aim at maximising flood safety as the primary need, whilst optimising for other important regional needs such as water availability, recreation and biodiversity.
- There is a critical need to triple the annual investments in NbS globally by 2030².
- The study aims to initiate a NbS pilot project delivering flood risk reduction services in the region of Thessaly.

NbS are increasingly seen as effective measures to address water-related climate risks and have been globally acknowledged as one of the key tools to deliver on climate adaptation and mitigation objectives (OECD, 2021; Swiss Re, 2021 EC, 2021; UN, 2021; UNDRR, 2021; TNC 2019; IUCN 2016).

The ambition of the study³ is to conduct a preliminary assessment of the feasibility of Nature-based Solutions (NbS) and their ability to deliver flood risk reduction services in the Pineios river catchment in the Thessaly Region in Greece. The geographical scope of the study is the Pineios river catchment in the Thessaly region in Greece, with a specific focus on two out of the four prefectures: Trikala and Karditsa⁴. Although the recommendations could be relevant for more types of floods, the study focuses primarily on river flooding, which is the most common type of flood in the study area and therefore represents a particular challenge⁵.

The main water-related challenges facing the Thessaly region can be summarised as follows:
- Occurrence of extreme flood events⁶
- Water scarcity during dry periods and over-exploitation of groundwater aquifers⁷
- Loss of biodiversity and native habitat⁸

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² UN, 2021
³ Meaning the pre-feasibility study for the Thessaly region, Greece.
⁴ Described in Chapter 2
⁵ River or “fluvial” floods occur when water levels exceed the channel capacity and spill into adjacent areas. The water level rise could be due to excessive rain or snowmelt. Pluvial floods (flash flood and surface water flood) occur when an extreme rainfall event creates a flood because an urban drainage system is overwhelmed and/or a retention capacity of the environment is exceeded. Pluvial flood is independent of an overflowing water body and can happen anywhere. Coastal flooding (storm surge) is the inundation of land areas along the coast by seawater (See EEA, Zurich).
⁶ Large parts of the Pineios river basin are characterised as Areas of Potential significant Flood Risk (APSFR) based on the respective Flood Risk Management Plan (FRMP).
⁷ Overall, in the Pineios river basin, extensive agricultural activities have resulted in large pressures on groundwater resources. Irrigation for agriculture takes up to 95 % of the total water use.
⁸ The Pineios delta supports great biodiversity of flora and fauna of significant ecological importance. The delta is designated as a “Special Protection Area” under the NATURA 2000 network (GR1420015) and a CORINE biotope (A00020006). However, most of the native habitats in the Thessaly plain have been cleared in the past.
NbS are expected to **maximise the potential of natural systems to deliver critical services**: flood risk reduction and water availability. In addition to grey infrastructure⁹, such as dams and dikes, the integration of watershed and ground water storage is essential for mitigating floods and droughts. Solutions based on nature such as wetlands, soil-sand ponds, forests and flood plains could be extremely effective in addressing sustainable water management.

This study focuses especially on the role of NbS, although the project team is conscious that oftentimes the portfolio of solutions could include a series of mixed natural-grey solutions that do not only consist of natural components (e.g., plants, trees, soil) but also include engineered solutions (e.g., employing building materials such as concrete, steel, and gravel). Consequently, the study assesses NbS which could be implemented either as stand-alone projects, or as green dimensions of grey infrastructure projects.

The assumption of the study team is that river flooding is a natural phenomenon that will happen in the future regardless of the measures in place. However, the study explores how to **limit the severity of flooding and safeguard communities and valuable areas through the implementation of NbS on a regional scale.** In other words, the aim of the study is to identify potentially suitable interventions that could help to mitigate the unwanted impacts of river floods on communities, industries and infrastructure networks.¹⁰ The proposed interventions aim at maximising flood safety as the primary need, whilst optimising for other important regional needs¹¹ such as water availability, recreation and biodiversity¹² (Figure 1-1).¹³ For example, NbS interventions are expected to tackle the existing water crises that affects farmers and their production. Farmers are seen as one of key beneficiaries.

This study is the first step towards the development of a **Feasibility study (FS)** that

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9 Grey infrastructure usually refers to the traditional methods of managing water, using man-made, constructed assets, which are most often watertight and designed to prevent any type of ecosystem from growing on them. It includes channels, pipes, sewers and sewage treatment works, ditches, dikes, dams, and so on. It owes its name to the fact that is often made of concrete. Unlike green infrastructure, grey infrastructure typically does not deliver multiple benefits (NWRM).

10 Floods need to be treated as a regional challenge.

11 The local needs were identified through series of in-person interviews and a workshop with local stakeholders and project beneficiaries.

12 The IUCN’s Global Standard for NbS sets Biodiversity as one of the key benefits that NbS projects ought to deliver to be considered NbS: https://www.iucn.org/theme/nature-based-solutions/resources/iucn-global-standard-nbs.

13 The figure depicts communities, industries and infrastructure in the inner rings and flood safety, water availability, recreation and biodiversity in thee outer rings. The order from inner to outer rings represents prioritisation of local stakeholders (e.g., flood safety being typically perceived as more important than biodiversity).
would validate the present assumptions and recommendations and initiate its pilot project (Figure 1-2).

### Pre-feasibility

**Figure 1-2. Guiding questions for integrating NbS in each stage of project cycle**

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<td>What is the local absorption capacity, social acceptance, costs, and benefits profile for prioritised NbS options?</td>
<td>What is the institutional vision and concrete technical objectives?</td>
<td>How can operational efficiency and transparency be promoted?</td>
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<tr>
<td>Which stakeholders care and why?</td>
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<td>What is the target implementation scenario and do funders believe it has attractive benefits relative to costs?</td>
<td>How can field monitoring be used to validate results?</td>
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<td>Is there a favourable institutional context?</td>
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<td>What is the target governance, funding, and operational arrangement to achieve those objectives?</td>
<td>Do core programme objectives require revision?</td>
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<td>Can collective action enhance outcomes?</td>
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<td>What NbS options are most relevant?</td>
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The study focused on the following objectives:

1. Establishment of a technical Working Group with Greek and international experts to obtain high-level knowledge and experience for assessing the challenges and proposing solutions to address local needs.
2. Articulation of water-related challenges in the region of Thessaly.
3. Mapping the stakeholder landscape and institutional profile of actors.
4. Mapping existing local policies, plans and initiatives in flood prevention.
5. Identification of potential areas for NbS implementation that can be an opportunity for a pilot project.
6. Proposal of a set of potential pilot projects likely to be suitable for the region.
7. Initial assessment of benefits of proposed NbS.
8. Feasibility assessment of proposed NbS.

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14 The figure was adapted from the The Nature Conservancy (TNC) training on NbS.
1.1 The approach: the role of Nature-based Solutions

Nature is part of the ‘infrastructure portfolio’ of every country and economy. In many cases, built infrastructure has natural counterparts, which, based on their capacity, could complement, augment or even replace conventionally built infrastructure. For example, a conventional dam built for mitigating flooding can be partly or fully substituted by a constructed or natural wetland (or a floodplain) that can provide the same or similar performance: controlling the discharge flow by lowering the maximum flow and increasing the lag time (Baltas, 2022, GIB, 2019).

Grey infrastructure comprises artificially constructed systems, built from materials such as steel and concrete to deliver a specific service (such as a conventional water treatment plant). Usually, grey infrastructure is resource-intensive, involves substantial operation and maintenance costs and often entails environmental impacts. Furthermore, grey infrastructure often relies on artificial structures and systems that are increasingly being recognised as less adaptable to changing operating conditions than their NbS counterparts.

In contrast, Nature-based Solutions take the form of natural systems, which are primarily composed of flora, fauna, natural materials (e.g., rocks, soil and sand) and water, providing infrastructure-like services (e.g., a wetland that has water treatment capabilities).

Various concepts and different terminology for using nature in both the human-built and natural environments have been developed over the past decades. This includes “natural infrastructure”, “green infrastructure”, “building with nature”, ecosystem-based adaptation or ecological engineering, each of which focuses on the benefits that nature can provide to society. Nature-based Solutions is an umbrella concept unifying all the above approaches.

Nature Based Solutions (NbS): are defined by the European Commission (EC) and the International Union for Conservation of Nature (Cohen-Shacham, 2016) as follows:

“Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions” (EC).

“Actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits” (IUCN).

---

15 Krchnak, 2011, p. 3
16 Cohen-Shacham, 2016, p. 20
17 For example, in the case of flood risk management, whereas flood-control infrastructures such as levees and dams often degrade aquatic habitat by altering the natural river flow regime and cut off floodplains from rivers, preserving floodplains and/or reconnecting them to rivers can instead provide flood management benefits while also conserving ecosystem values and functions; Cohen-Shacham, E., Walters, G., Janzen, C. and Maginnis, S. (eds.) (2016). (Cohen-Shacham, 2016, p.12).
18 WRI, 2013 & WBCSD, 2017
19 Mazza L., 2011
20 De Vriend et al., 2014
22 Cohen-Shacham, 2016, p.12.
Awareness has recently grown that nature can provide many cost-effective ways of adapting to climate change whilst also protecting the ecosystem upon which we depend. NbS often require a lower capital investment and have lower operating and maintenance costs (e.g., by being less labour-intensive and more energy-efficient). Furthermore, NbS have been cited as significantly reducing or mitigating project risks, lowering economic costs, creating more liveable environments for people and enhancing biological diversity. Table 1-1 shows the different characteristics of grey and NbS interventions, including their respective benefits.

Table 1-1. Comparison of grey and NbS

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Grey</th>
<th>NbS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intentionally designed</td>
<td>Always</td>
<td>Sometimes</td>
</tr>
<tr>
<td>Artificially constructed</td>
<td>Always</td>
<td>Sometimes</td>
</tr>
<tr>
<td>Managed/operated/maintained through human intervention</td>
<td>Always</td>
<td>Sometimes</td>
</tr>
<tr>
<td>Contains “natural” components</td>
<td>Rarely</td>
<td>Always</td>
</tr>
<tr>
<td>Provides environmental benefits</td>
<td>Rarely</td>
<td>Always</td>
</tr>
<tr>
<td>Provides social benefits</td>
<td>Often</td>
<td>Often</td>
</tr>
<tr>
<td>Provides economic benefits</td>
<td>Often</td>
<td>Often</td>
</tr>
<tr>
<td>Feasible in urban environments</td>
<td>Often (Due to being perceived as more space efficient)</td>
<td>Often (Less feasible in cases where NbS requires more space than is available)</td>
</tr>
<tr>
<td>Cost-effective</td>
<td>Context dependent (Commonly involves higher maintenance and construction costs)</td>
<td>Context dependent (Often favourable due to lower O&amp;M costs. Same levels of service - not always possible)</td>
</tr>
<tr>
<td>Risk mitigation potential⁵⁵</td>
<td>Typically, lower than hybrid and natural solutions.</td>
<td>Typically, high</td>
</tr>
<tr>
<td>Climate change adaptation potential</td>
<td>Low – Medium</td>
<td>High</td>
</tr>
<tr>
<td>Common examples</td>
<td>Roads, railways, power stations, power transmission, water treatment plants, dikes, tunnels, dams, pipelines, airports, shipping yards, etc.</td>
<td>Wetlands, forests, private gardens, shrubs, peatlands, green roofs, etc.</td>
</tr>
</tbody>
</table>

⁵⁵ Conventional infrastructure often relies on artificial structures and systems that are increasingly being recognised as less adaptable to changing operating conditions than their NbS counterparts. For example, a wastewater treatment plant that relies on chemical treatment processes and built storages will often be less resilient to changing water flows than a solution that incorporates wetland treatment that can better buffer flow peaks.
The Global Commission on Adaptation highlighted adaptation solutions as often being "no regret", i.e., worth pursuing regardless of the ultimate climate path. This is due to their multiple co-benefits, particularly for **Nature-based Solutions** and disaster risk prevention, and the "triple dividend" of adaptation (EC, 2021):

1. **Avoiding future losses** (human, natural and material);
2. **Generating economic benefits** by reducing risks and co-benefits (social, environmental and cultural);
3. **Increasing productivity and stimulating innovation**.

NbS have become much more central in recent years as viable measures in the context of **disaster risk reduction** and **climate change adaptation**. For example, the recently published **EU Strategy on Adaptation to Climate Change** stresses the importance of NbS in the overall portfolio of adaptation measures (2021)

### 1.1.1. **Nature-based Solutions for flood safety**

NbS for flood safety include a variety of different solutions composed primarily of natural components, for example, a regeneration of rivers and flood plains, creation of flood storage areas, and reforestation of riparian areas. **Figure 1-3** depicts typology of NbS based on the level of engineering applied to biodiversity and ecosystems and target benefits. For example, existing natural ecosystems (red colour) such as large forest tend to provide more types of ecosystem services (e.g., clean air, water management, biodiversity) to multiple stakeholders, whereas new ecosystems (green colour), often engineered, such as retention pond offer one or two specific ecosystem services to smaller number of stakeholders.

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26 The EU Strategy on Adaptation to Climate Change objectives include NbS (2021p. 11-12): 1. **Implementing nature-based solutions on a larger scale would increase climate resilience and contribute to multiple Green Deal objectives.** Blue-green (as opposed to grey) infrastructures are multipurpose, "no regret" solutions and simultaneously provide environmental, social and economic benefits and help build climate resilience. Nature-based solutions are essential for sustaining healthy water, oceans and soils. 2. **They must play a bigger role in land-use management and infrastructure planning to reduce costs, provide climate-resilient services, and improve compliance with Water Framework Directive requirements for good ecological status.** Using nature-based solutions inland, including the restoration of the sponge-like function of soils, will boost the supply of clean, fresh water and reduce risk of flooding. 3. **Europe needs to leverage more investments in nature-based solutions to generate gains for adaptation, mitigation, disaster risk reduction, biodiversity, and health.** Investments in nature-based solutions must be viable over the long-term, because climate change is amplifying stresses on ecosystems.

27 Delivering flood risk reduction services (benefits).

28 A comprehensive list of Nature-based Solutions can be found on the following link: [http://nwrm.eu/measures-catalogue](http://nwrm.eu/measures-catalogue). Other useful resources include [Handbook for Nature-Based Solutions](http://nwrm.eu/measures-catalogue).

29 Source: adapted from Eggermont at al., 2015 & TNC traning on NbS.
Table 1-2. Categories of NbS Interventions

<table>
<thead>
<tr>
<th>Categories of NbS Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of natural ecosystem</td>
</tr>
<tr>
<td>is an intervention that prevents, or greatly limits, overexploitation of existing natural</td>
</tr>
<tr>
<td>resources to achieve the long-term conservation of nature.</td>
</tr>
<tr>
<td>Managed or restored ecosystem</td>
</tr>
<tr>
<td>is an active or passive intervention that involves returning degraded, damaged or destroyed</td>
</tr>
<tr>
<td>ecosystems to pre-disturbance state.</td>
</tr>
<tr>
<td>Creation of new ecosystem</td>
</tr>
<tr>
<td>involves the establishment, protection and/or management of artificial “new” ecosystems.</td>
</tr>
<tr>
<td>This includes non-natural tree stands, artificial grasslands, created artificial wetlands</td>
</tr>
<tr>
<td>(not restored) and urban green infrastructure.</td>
</tr>
</tbody>
</table>

Table 1-3 provides an overview of most common NbS for to deliver flood risk reduction services in the context of riverine ecosystems.

Table 1-3. Most common NbS delivering flood risk reduction services

<table>
<thead>
<tr>
<th>NbS Intervention</th>
<th>Description</th>
<th>Benefit</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floodplain restoration and management³³</td>
<td>Restoring retention capacity and ecosystem functions of floodplains, by reconnecting them to the river.</td>
<td>Flood risk reduction</td>
<td></td>
</tr>
<tr>
<td>River restoration</td>
<td>Includes NbS interventions such as re-naturalisation of polder areas³⁴, stream-bed renaturalisation³⁵, reconnection of oxbow lakes and similar features³⁶, and reconnection of seasonal streams³⁷.</td>
<td>Flood risk reduction</td>
<td></td>
</tr>
</tbody>
</table>

---

³⁰ Targeted habitat protection is the most common form of protection and refers to all conservation activities to protect target ecosystems, including national park designation, aiming to provide, for example, ground water protection of a specific area.

³¹ This category improves the delivery of selected (ecosystem) services. Examples include enhancing tree species and genetic diversity to increase forest resilience to extreme events, reforestation, grassland revegetation, riparian restoration, wetlands and floodplain restoration and invasive species removal.

³² The typology of measures comes from the Natural Water Retention Measures Catalogue, which can be found on the following link: [http://nwrm.eu/measures-catalogue](http://nwrm.eu/measures-catalogue). Another useful resource is also the *Handbook for Nature-Based Solutions*.

³³ Restoring the floodplain roles requires measures such as (NWRM, 2022): modification of the channel, creation of lakes or ponds in the floodplain, new/modification of agricultural practices, afforestation, plantation of native grasses, shrubs and trees, wetland creation etc.

³⁴ [http://nwrm.eu/measure/re-naturalisation-polder-areas](http://nwrm.eu/measure/re-naturalisation-polder-areas)

³⁵ [http://nwrm.eu/measure/stream-bed-re-naturalization](http://nwrm.eu/measure/stream-bed-re-naturalization)


<table>
<thead>
<tr>
<th>Wetland restoration and management</th>
<th>It can involve technical, spatially large-scale measures (including the installation of ditches for rewetting or the cutback of dikes to enable flooding).</th>
<th>Flood risk reduction, Biodiversity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basins, ponds, and lakes</td>
<td>Provide temporary or permanent storage for water to flatten the water discharge peak.</td>
<td>Flood risk reduction, water availability</td>
</tr>
<tr>
<td>Low/No till agriculture</td>
<td>Improvements to the management of the agricultural land to increase its retention capacity (e.g., agroforestry\textsuperscript{38}).</td>
<td>Flood risk reduction, Biodiversity</td>
</tr>
<tr>
<td>Natural bank stabilisation</td>
<td>Riverbank renaturalisation consists of recovering its ecological components, thus allowing the bank to be stabilised and rivers to move more freely, resulting in decreased water flow and erosion, and enhanced biodiversity.</td>
<td>Biodiversity, Erosion control</td>
</tr>
<tr>
<td>Maintenance of forests</td>
<td>Protection of existing upstream forests. Forest soils generally have better infiltration capacity than other land cover types and may act as a “sponge”, slowly releasing rainfall.</td>
<td>Flood risk reduction, water quality, Biodiversity</td>
</tr>
<tr>
<td>Forest riparian buffers</td>
<td>Conservation of existing or restoration of “new” forests alongside river streams and other water bodies.</td>
<td>Recreational opportunities, Erosion control</td>
</tr>
<tr>
<td>Targeted planting for 'catching' precipitation</td>
<td>Establishment of new forests &amp; shrubs (i.e., habitats) to enhance the retention capacity of the watershed (e.g., reforestation).</td>
<td>Flood risk reduction, Biodiversity</td>
</tr>
<tr>
<td>Restoration of natural infiltration</td>
<td>Small stone barriers installed in creeks &amp; riverbeds in the mountains to reduce velocity and retain water upstream.</td>
<td>Flood risk reduction</td>
</tr>
<tr>
<td>Coarse woody debris</td>
<td>Deadfall of tree stems or stumps that either fall into or are deliberately placed in streams. Coarse woody debris will generally slow water flow velocity and can reduce the peak of flood hydrographs.</td>
<td>Flood risk reduction, Biodiversity</td>
</tr>
<tr>
<td>Removal of dams and other longitudinal barriers</td>
<td>Dams and other longitudinal barriers are obstacles crossing the river section and causing discontinuities for sediment and fauna.</td>
<td>Flood risk reduction, Biodiversity</td>
</tr>
</tbody>
</table>

\textsuperscript{38} Agroforestry is a land use management system in which trees or shrubs are grown around or among crops or pastureland.
1.1.2. **Expected benefits of Nature-based Solutions**

NbS are an excellent opportunity to address variety of needs such as those identified in this study for the Thessaly region as showed in Figure 1-1. To measure the impact of NbS interventions there is a need to define indicators and setup monitoring & evaluation framework.

The NbS impact evaluation relies on the adoption of quantitative and qualitative impact indicators. These serve as means for assessing the progress of an adopted pathway targeted at achieving specific objectives (EC, 2021b). The below table provides a list of potential key performance indicators (KPIs) that can help to monitor the performance and impact of NbS toward the local needs that have been formulated by local stakeholders. This list provides some examples, however, these indicators will need to be precisely identified in a feasibility study.

*Table 1-4. Potential key performance indicators (KPI’s) to measure the impact of NbS*.  

<table>
<thead>
<tr>
<th>Need</th>
<th>Key performance Indicator (KPI)</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic benefits</td>
<td><strong>NbS cost/ benefit analysis: avoided costs</strong></td>
<td>€</td>
</tr>
<tr>
<td></td>
<td><strong>Reduced / avoided damage costs from hydro meteorological risk reduction</strong></td>
<td>€/year</td>
</tr>
<tr>
<td></td>
<td><strong>cost of insurance / availability of insurance</strong></td>
<td>€</td>
</tr>
<tr>
<td>Flood risk reduction</td>
<td><strong>Mean annual direct and indirect economic losses due to flooding.</strong></td>
<td>€</td>
</tr>
<tr>
<td></td>
<td><strong>Peak flow rate</strong></td>
<td>m³/s</td>
</tr>
<tr>
<td></td>
<td><strong>Peak flood volume</strong></td>
<td>m³</td>
</tr>
<tr>
<td></td>
<td><strong>Risk to critical infrastructure</strong></td>
<td>%</td>
</tr>
<tr>
<td></td>
<td><strong>Area exposed to flood risk</strong></td>
<td>ha</td>
</tr>
<tr>
<td></td>
<td><strong>Local population exposed to flood risk</strong></td>
<td>No. / ha</td>
</tr>
<tr>
<td></td>
<td><strong>Agriculture land exposed to flood risk</strong></td>
<td>ha</td>
</tr>
<tr>
<td>Aquifer recharge &amp; surface water availability</td>
<td><strong>Net surface water availability</strong></td>
<td>m³/year</td>
</tr>
<tr>
<td></td>
<td><strong>Quantitative status of groundwater</strong></td>
<td>Good or Poor</td>
</tr>
<tr>
<td></td>
<td><strong>Depth to groundwater</strong></td>
<td>m</td>
</tr>
<tr>
<td></td>
<td><strong>Level of groundwater table</strong></td>
<td>m below ground surface</td>
</tr>
<tr>
<td>Recreation</td>
<td><strong>New activities in tourism sector</strong></td>
<td>Number (1-5)</td>
</tr>
<tr>
<td></td>
<td><strong>Increase in tourism</strong></td>
<td>Mean no. visitors / day per year</td>
</tr>
<tr>
<td></td>
<td><strong>New pedestrian, cycling path</strong></td>
<td>km</td>
</tr>
<tr>
<td></td>
<td><strong>Number of visitors to recreational areas</strong></td>
<td>No.</td>
</tr>
<tr>
<td></td>
<td><strong>Green space accessibility</strong></td>
<td>%</td>
</tr>
<tr>
<td></td>
<td><strong>Share of green rural/urban areas</strong></td>
<td>%</td>
</tr>
<tr>
<td>Biodiversity</td>
<td><strong>Number of native species</strong></td>
<td>Number</td>
</tr>
<tr>
<td></td>
<td><strong>Number of invasive alien species</strong></td>
<td>Number</td>
</tr>
<tr>
<td></td>
<td><strong>Extent of habitat for native pollinator species</strong></td>
<td>ha</td>
</tr>
<tr>
<td></td>
<td><strong>Number of native bird species within a defined urban area</strong></td>
<td>No./ha</td>
</tr>
<tr>
<td></td>
<td><strong>Proportion of protected areas</strong></td>
<td>%</td>
</tr>
</tbody>
</table>

39 EC, 2021
1.2. The Broader Context: Financing Nature-based Solutions

Current investment in NbS must increase first and foremost to address the biodiversity crisis, to help meet EU and international goals for climate change mitigation and adaptation, and to support the transition to a more nature-positive economy (Figure 1-4).

NbS projects may provide several attractive features for investors, such as easier long-term amortisation, relative ease of budgeting management costs, and lower maintenance and rehabilitation costs than for grey infrastructure. To triple the annual investment in NbS by 2030, as indicated on Figure 1-4, this challenge needs to be addressed on a smaller scale and replicated further. The Thessaly case represents a successful regional case that could act as a role model for other regions in Greece and other European countries.

Costs of Nature-based Solutions in Greece

The cost of different NbS measures depends on many variables, such as the cost of work and materials locally, the size of the proposed NbS interventions and their specific location, maintenance and operation costs, etc. The project team can conclude that there is little data on the cost of different NbS types for Greece, due to a lack of existing NbS interventions implemented on the ground in this country. However, the project team has identified and acquired real cost data for two semi-natural water retention ponds that have been recently constructed for flood mitigation in the Spercheios river catchment in Greece. This can provide at least some indication on costs for one type of NbS intervention and as well as its retention capacity (performance):

- **Pond 1**: CAPEX of 1.1 M € for a capacity of 600,000 m³
- **Pond 2**: CAPEX of 180 k € for a capacity of 30,000 m³

The above costs include design, modelling, approvals, construction, operationalisation and impact assessment and exclude maintenance and land acquisition. Costs for other types of NbS (e.g. wetlands, forests, riparian buffers) can vary significantly, and further technical studies will need to be conducted.

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40 Loupis, 2021
in order to establish these cost estimations. However, international experience from already implemented and monitored NbS projects (e.g., Hondsbossche and Pettemer sea dunes\textsuperscript{41}) shows that NbS are much more flexible to future events, and that future maintenance and operation costs are typically lower overall.

1.3. Methodology

The project team relied on the Nature for Catchments Launchramp (NCL) methodology when conducting the study. It is designed to support large investors, primarily development finance institutions (DFIs), in sourcing a pipeline of bankable projects and to enable capital seekers (e.g., public decision-makers) to better access catalytic capital to develop impactful infrastructure projects. NCL contributes to the increase of annual investment into nature and thus contributing to a number of Sustainable Development Goals (SDGs), such as SDG 3, SDG 6, SDG 9, SDG 11, SDG 13.

The methodology was developed by the project team prior to conducting the study. The Nature for Catchments Launchramp (NCL) methodology is a project origination process for Nature-based Solutions (NbS) interventions that can complement or replace conventional 'grey' infrastructure, in order to limit recurring impacts of floods on communities, industries and infrastructure networks in a more sustainable and cost-effective manner. The methodology uses a participatory approach with local stakeholders to establish the policy, governance, finance, and technical considerations needed to implement NbS. The result is a catchment level pre-feasibility study that contains specific NbS interventions suitable for development and financing. The NCL methodology addresses key barriers hindering investment in NbS at scale, including: cost and complexity of project origination; bankability; governance; regulation; and local capacity. \textbf{Table 1-5} shows key activities that have been performed under the study and which are a basis for the outcomes and recommendations.

\textbf{Table 1-5. Activities undertaken under this study following the NCL methodology approach.}

<table>
<thead>
<tr>
<th>Desk-based research &amp; collection of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Baseline assessment of the characterisation of the Thessaly Region.</td>
</tr>
<tr>
<td>- Gathering information on the ecosystem types present in the area.</td>
</tr>
<tr>
<td>- Identification of future development projects planned in or adjacent to the NBS site,</td>
</tr>
<tr>
<td>- Collection of historical data, comparing aerial photos of 1945/1960 and today from the Greek Cadastre &amp; historical flood data (e.g., the presence of historical (1943 &amp;1944) flood plains and wetlands).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mapping and analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Mapping stakeholders that have a stake in improving flood risk.</td>
</tr>
<tr>
<td>- Mapping core partner group to take project preparation forward.</td>
</tr>
<tr>
<td>- Establishment of two new collaborations with Greek entities (WWF GR, the National Technical University of Athens).</td>
</tr>
</tbody>
</table>

\textsuperscript{41} [https://www.youtube.com/watch?v=gTB1mQYsI64](https://www.youtube.com/watch?v=gTB1mQYsI64)
- Mapping policies, legal frameworks at the EU, national and the catchment level (e.g., the Flood Risk management Plan (FRMP) of Thessaly).
- Mapping roles and responsibilities for flood institutional arrangements against best practice principles & identification whether there is a need for policy / governance reform.
- High-level analysis of infrastructure finance and insurance market.

**In-personal interviews, dialogues**

- Organisation of interviews with local decision makers: interviews with the mayors of the ten municipalities of western Thessaly, the head of the Region of Thessaly and the coordinator of the Decentralised Administrator of Thessaly & Sterea Ellada.
- The input of the participants of Trikala workshop from 25-26 November 2021: delivery of NbS training and co-design exercise with maps to develop capacities on the local level, engage local decision makers in the co-design of NbS interventions, and collect local views and knowledge.
- Identification of needs and concerns. Building trust relationships.

**Assessment**

- Establishment of an expert group dealing with technicalities (i.e., NbS Technical Working group).
- Selection of site(s) for possible implementation of NbS.
- Flood risk modelling for selected sub-basins to identify excess volumes of water in a 50-year flood.
- Proposition of NbS priority interventions considered for a pilot project.
- Assessment of benefits of NbS interventions and their feasibility.
- Hydrologic Engineering Center’s (CEIWR-HEC) River Analysis System (HEC-RAS)
OVERVIEW OF WATER-RELATED CHALLENGES IN THE THESSALY RIVER BASIN DISTRICT
2. OVERVIEW OF WATER-RELATED CHALLENGES IN THE THESSALY RIVER BASIN DISTRICT

Summary box

- The occurrence of extreme flood events is one of the most destructive natural hazards in the Thessaly region with negative impacts on communities and the economy. Large parts of the Pineios river basin are characterised as Areas of Potential Significant Flood Risk.
- The Thessaly Region Basin District constitutes the most important region for the agricultural sector in Greece. The plain of Thessaly constitutes the most productive Greek agricultural territory. The irrigation needs for agriculture take up to 95% of the total water use, making the region extremely vulnerable to water scarcity in summer.

Thessaly region has always been susceptible to river floods and they will continue to occur despite any efforts to prevent them from happening. Initially, this is because of the topography: an extended flat territory surrounded by mountains, forming a river basin as large as 11,062 km². Any extreme precipitation will result in some sort of “less or more severe” flooding event in the plain area. The Thessaly River Basin District (RBD) includes two basins, the Pineios basin and the Almiros basin. The present chapter elaborated on the watershed conditions, water related challenges and other factors contributing to floods.

Table 2-1. Information on the Pineios river basin

<table>
<thead>
<tr>
<th>THE RIVER BASIN DISTRICT (RBD) DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area of the Thessaly RBD</td>
</tr>
<tr>
<td>Pineios river basin</td>
</tr>
<tr>
<td>Population</td>
</tr>
<tr>
<td>Estimated annual water consumption</td>
</tr>
</tbody>
</table>

2.1. Overview of the watershed conditions

Topography
The plain of Thessaly is divided by a low-lying hill area into a western region (Trikala-Karditsa) and an eastern region (Larisa). The Pineios river is the third longest river in Greece. It discharges into the Aegean Sea, forming a significant delta after crossing the eastern part of central Greece. Its length is

---

43 Idem According to the 2011 census, the population of the RBD is 732,762 inhabitants, indicating a decrease of 2.3% compared with the previous census.
about 205 km. The Pineios river basin covers an area of about 11,062 km\(^2\). The Pineios delta supports great biodiversity of flora and fauna of significant ecological importance.

**Figure 2-1** presents the land uses for the Pineios river basin. The predominant land cover type according to the Corine Land Cover (CLC) classification (2018) is permanently irrigated land (24%), followed by non-irrigated arable land (17%), sclerophyllous vegetation (16%), natural grasslands (9%) and broad-leaved forests (8%).

The Pineios basin drains a large, geologically heterogeneous area, through extensive hydrographic networks. The main tributaries of the Pineios river are: Enipeas, Farsaliotis, Sofaditis, Kalentzis, Megas, Pamisos, Portaikos, Lithaios, Neochoritis and Titarisios rivers. Enipeas, Farsaliotis, Sofaditis, Kalentzis, Megas, Pamisos, and Portaikos are located in the southwest of the basin, while the rest are located in the north of the basin.

**Climate and rainfall**

In general, the wet period is from November to February with the rainiest months being November and December. On the other hand, during the summer months (from June to August) rainfall is practically non-existent. Mean annual flow for the Pineios river basin is estimated at about 3,5000 hm\(^3\). The regime of the Pineios river flow, for the main stem, can be characterised as perennial\(^{44}\), with large differences. For example, near the delta, its mean average flow ranges from more than 150 m\(^3\)/s in February and March to about 10 m\(^3\)/s in August and September\(^{45}\).

**Water consumption**

Overall, the Thessaly RBD constitutes the most important region for the agricultural sector in Greece. At the same time, it can also be considered to be one of the most water-intensive regions in Greece.

\(^{44}\) A stream that has flowing water year-round during a typical year.

\(^{45}\) Bathrellos et al., 2018
About 84% of total annual demand derives from abstractions from groundwater bodies through borehole exploitation, mainly in order to meet irrigation-related water demand. About 120 hm$^3$ derives from water transfer outside the river basin district (Plastira Reservoir) and is used to supplement the water supply the needs of the greater Karditsa area with regard to both irrigation and drinking water. Moreover, the total irrigated area is estimated at about 236,092 ha. The area irrigated from water boreholes and private works is estimated at about 67% (76,950 ha) of the total irrigated area, while the rest, 34% (1,632 ha) is irrigated using public irrigation plans$^{46}$.

### 2.2. Water-related challenges

**River Floods**

The occurrence of extreme flood events is one of the most destructive natural hazards with significant negative impacts on communities and the economy. Floods in Greece are a common occurrence. Due to climate change, their severity has increased over the last few decades, leading to significant human losses and damages to infrastructures, communities and economic sectors (e.g., agriculture). Specifically, the neighbouring districts of Karditsa and Trikala, in Central Greece, suffer from extreme, high-intensity rainfall events and severe historic floods$^{47}$.

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$^{46}$ Koutsoyiannis et al., 2008

$^{47}$ On 18 September 2020, Medicane Ianos, an unprecedented catastrophic flood considered one of the most disruptive events to hit the region, caused estimated economic losses totaling between EUR 0.5 – 1 billion. The accumulated rainfall exceeded 250 mm in less than 24 hours and resulted in widespread flooding, which caused damages to more than 5,000 households and shops in the city of Karditsa and 15 other villages, while a total of 15 bridges collapsed.
Figure 2-2 presents Areas of Potential Significant Flood Risk (APSFR) based on the Flood Risk Management Plan for the River Basins of the River Basin District of Thessaly-EL08 (2018). It can be observed that a large part of the Pineios river basin qualifies as APSFR. In addition to that, Annex Table 1 (Annex 1) presents the significant historical flood events reported by the Flood Risk Management Plan for the River Basins of the River Basin District of Thessaly-EL08 (2018).

Lack of water availability
The plain of Thessaly constitutes the most productive Greek agricultural territory, with more than 50% covered by agricultural land (precisely 51.7%). The other main land uses are urban areas (2.5%) and forest (45%) as previously presented (Figure 2-1). The main crops are winter wheat, maize, alfalfa, and cotton. More than 50% of the agricultural land is irrigated, and as a result, irrigation for agriculture takes up to 95% of the total water use.

According to the Water Framework Directive (WFD) 2nd River Basin Management Plan, the majority of water bodies in the RBD of Thessaly were characterised as less than good. A major impact of agriculture to groundwater is the decline of the water table. The expansion of the irrigated area, which increased from 105,000 ha in 1977 to 242,447 ha in 1994, resulted in declines of water table heads from a depth of two to five metres below ground to 100 - 150 metres or more in the central parts of the Pineios basin. Loukas et al. (2007) assessed potential of surface and groundwater resources by modelling demand of water sectors and water balance in the main sub-basins of Thessaly.

2.3. Factors contributing to floods in Thessaly

There are three reasons contributing to floods that are not related to natural geomorphology but rather to extended human interventions that occurred even almost a century ago, due to poor governance in regards to water management, and to deficient existent infrastructures:

- Extensive works were carried out in Thessaly in the middle of the 1900s and during the late 1960s/early 1970s. The purpose of the first round of interventions (around the 1940s) was to acquire more agricultural land through the drainage of permanent marshes and floodplains and the diversion of main rivers. During the second round of interventions (1960/1970), the purpose was land redistribution, however “wetlands were drained, riverbeds were redesigned and managed, and smaller streams receded and disappeared”.

As a result of those works, areas naturally regulating floods disappeared resulting in the increased risk that the area faces in the present period. More information on the past human interventions is give in Annex 1.

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48 The significant flood events presented herein cover the period from 2016 to 2018. The table presents the date of the flood, what was impacted from the flood and the coordinates of the flood event. Coordinates are in GGRS 87, which is the projected coordinate system for Greece. It can be observed that the main impact of flooding is on infrastructure (e.g., bridges etc.) and on rural land uses (e.g., crops, livestock etc.).
49 Psomas et al., 2016
50 Dimopoulos et al., 2003
51 Intensive cultivation of water-intensive crops, such as cotton and maize, has led to a remarkable increase in water demand, which is usually addressed by the over-exploitation of groundwater. This over-exploitation, especially during extended drought periods, has accelerated the decline of water resources, both in quantity (important decline of groundwater level) and quality. Overall, in the Pineios river basin, extensive agricultural activities have resulted in large pressures on the groundwater resources.
52 Galanis, 1933.
• The meetings with the local and regional authorities and the workshop in Trikala organised as a preparatory step for this pre-feasibility report have also revealed inappropriate practices and inadequate governance on a local scale. Among the inputs, many have mentioned inappropriate management of adjustable gates that have been installed in the rivers to control the water flow and create small water reservoirs for irrigation during the dry season. Contrary to what should be done in case of extreme events, many of these water gates remain closed, thus contributing to the creation of floods. In addition to that, many small-scale soil dams are created illegally by farmers for the same reason and despite the warnings by the authorities to remove them before the start of the rainy period, no such actions are made.

• Many bridges collapsed due to poor hydraulic design, since their hydraulic sections were proven inadequate for major flood events that are becoming a “new normal”. These poorly designed infrastructures act as a bottleneck by blocking the river flow, thus contributing to the flooding. Poor maintenance of the riverbed was mentioned also to be an issue, further reducing the effective hydraulic sections beneath the bridges.\(^{54}\)

Having recognised some of the reasons that are a direct cause of floods or exacerbate them when they occur, corrective and preventive actions such as improved governance and management, infrastructures improvement, better maintenance of the riverbeds can be planned to reduce the flood risk. Nevertheless, the main challenges such as the higher occurrence of extreme weather events resulting from climate change and the disappearance of natural flood regulating systems (e.g., floodplains, wetlands, as a result of past human interventions, will continue to put the area at risk.

\(^{54}\) Zekkos et al, 2020.
REGULATORY FRAMEWORK, INSTITUTIONAL ROLES & RESPONSIBILITIES, AND STAKEHOLDER ANALYSIS
3. REGULATORY FRAMEWORK, INSTITUTIONAL ROLES & RESPONSIBILITIES, AND STAKEHOLDER ANALYSIS

Summary box

- There is a clear regulatory framework in several areas, including water management, flood protection, agriculture, and conservation policy issues.
- A multi-level governance approach is used for decision and policy making when it comes to flood risk management, with stakeholders including municipalities, regions, national as well as decentralised institutions.
- The institutional framework is complex, with some overlap between functions.
- The number of beneficiaries when it comes to flood protection and other co-benefits is estimated as high.

Among the purposes of this study is the promotion of large-scale uptake of Nature-based Solutions as a mean to achieve broader sustainability objectives, with the primary goal to provide flood risk reduction services. The NbS approach – a key approach for the delivery of sustainable climate adaptation and mitigation projects – is integrated in the strategic objectives and adaptation ambition of the European Investment Bank (EIB), and especially stated and stressed in (i) EIB Climate Adaptation Plan (2021) and (ii) EIB Group Climate Bank Roadmap 2021-2025 (2020), as seen in Table 3-1.

Table 3-1. Key investment areas and focus areas for Green investment, included in EIB’s plan and roadmap

<table>
<thead>
<tr>
<th>CONNECTION OF EIB’S ADAPTATION PLAN AND ROADMAP WITH NBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>KEY INVESTMENT AREAS OF EIB (EIB Climate Adaptation Plan)</td>
</tr>
<tr>
<td>Coping with water scarcity and the increased risk of flooding</td>
</tr>
<tr>
<td>Strengthening Climate Resilience of Food Systems, Forests and Ecosystems</td>
</tr>
<tr>
<td>Innovation</td>
</tr>
<tr>
<td>Disaster risk management</td>
</tr>
<tr>
<td>FOCUS AREAS FOR GREEN INVESTMENT (EIB Group Climate Bank Roadmap 2021-2025)</td>
</tr>
<tr>
<td>Focus 1: Building greater resilience to climate change</td>
</tr>
<tr>
<td>Focus 7: Protecting nature</td>
</tr>
<tr>
<td>Focus 9: Sustainable cities and regions</td>
</tr>
<tr>
<td>Focus 10: Greening the financial system</td>
</tr>
<tr>
<td>Focus 11: Leading the green change globally</td>
</tr>
</tbody>
</table>

Chapter 3 identifies and provides relevant policy, legal frameworks and plans that could support the adoption of Nature-based Solution for flood mitigation and protection. EU-level policies and legal frameworks and their transposition to the Greek context are analysed. Following this, roles and responsibilities for flood risk management are mapped while finally, stakeholders and beneficiaries are presented in relation to ecosystem services, flood risk management, and willingness to cooperate.

Thessaly Region and especially western Thessaly (Prefectures of Karditsa and Trikala) is prone to flooding, as indicated by the Flood Risk Management Plan (FRMP) and depicted in Figure 3-1 (in blue). The following analysis is based on information provided in the flood risk assessment for the Pineios basin, as well as the description of the significant floods that was outlined in Chapter 2 and in Annex 1.

![Figure 3-1. Water Department of Thessaly (EL08) Potentially High Flood Risk Zones](image)

The existing EU legislation provides an institutional framework for all water bodies in EU countries. The Water Framework Directive (WFD) (2000/60/EC) (on water resources management), and the Floods Directive (2007/60/EC) are analysed while nature conservation policies are also considered, since NbS must have positive biodiversity returns according to the IUCN Global Standard for NbS (2020). Finally other initiatives in relation to the main land use in the area (agriculture), and initiatives related to drought and water scarcity are also presented.

3.1.1. EU Water Framework Directive (WFD) and Greece

The Greek Ministry of Environment and Energy is responsible for the implementation of the WFD and the coordination of authorities working on the aquatic environment. To implement the WFD, 14 Regional Water Directorates were created, as well as a specialised Central Water Agency, a governmental authority under the Ministry of the Environment and Energy (YPEN), in charge of the definition and oversight of Greek national water policy.

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55 In order to prepare this section, the project team has drawn on the analysis of relevant policy and governance arrangements for flood risk management, one of the NCL Methodology components.

56 Source: General Secretariat for Natural Environment & Water General Directorate of Water, October 2019
The river basin management plan (RBMP) for Thessaly (GR08) was adopted in 2014, the 2nd RBMP was adopted on the 21st of December 2017. The public consultation for the 3rd RBMPs (2022-2027) will start soon. The Thessaly basin has 86 water bodies, and according to the Report on the implementation of the Water Framework Directive River Basin Management Plans GR08 has the highest percentage of water bodies in poor and bad status with 40% (Figure 3-2).

In collaboration with the 14 Regional Water Authorities (Directorates), the Ministry of Environment and Energy formulates and, upon approval by the National Council for Water, implements the River Basin Management Plans (RBMPs). Greece revised its water management framework by adopting a new Water Law in 2003, as well as measures and procedures for integrated water resource management in 2007. The new legislation is based on the EU WFD, with its emphasis on adopting a river basin management approach, the recovery or protection of the ecological functions of water, economic evaluation, and full-cost recovery of water services.

### 3.1.2. EU Floods Directive and Greece

The Special Water Secretariat of the Ministry of Environment and Energy (EGY/RIS) is responsible for publishing Flood Risk and Hazard Maps for all water districts of the country within the scope of Directive 2007/60 / EC "Assessment and Flood Risk Management". The Flood Hazard Maps include rivers, streams, lakes and streams in Potentially High-Risk Flood Zones.

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According to the OECD\textsuperscript{61}, specific measures are present within the Flood Risk Management Plans (FRMPs) for all RBDs related to agriculture (“Rehabilitation of agricultural holdings damaged due to natural disasters”):

- Land use management plans in the catchments of torrents,
- Restructuring of cultivations in flooded areas,
- Restoration and upgrade of drainage systems in flat cultivation areas,
- Flood protection infrastructure,
- Development of early warning systems,
- Upgrading of emergency plans,
- Legislative action for the maintenance of torrents and rivers.

### 3.1.3. Drought Policy and Regional Climate Plan

The observed decrease in rainfall is leading to the growing incidence and severity of droughts. Recent drought events have been reported. Farmers can be supported to reduce drought risks within farm improvement plans, according to the Community Guidelines for State Aid in the Agriculture and Forestry Sector 2014-2020 (2014/C 204/01). “Strategic plans for the response to water scarcity and drought” are being developed for specific RBDs according to the RBMPs for the implementation of the WFD. However, no drought policy is currently in place in the Thessaly region. Similarly, the regional climate plan is not in force yet, though it is past the consultation stage and should come into force in the coming months.

### 3.1.4. Agricultural policy

The Ministry of Rural Development and Food (MRDF) also has authority when it comes to irrigation water management and agriculture.

Eco schemes\textsuperscript{62} are a part of the Common Agricultural Policy (“CAP”) reform to be implemented from 2023. They must be included in each country’s strategic plan, but their adoption by farmers is voluntary. They aim to encourage farmers to put in place climate-, environment- and animal-friendly practices that go beyond compulsory requirements set by the CAP and received additional compensation for it. Eco schemes will be allocated 25% of the budget for direct payments\textsuperscript{63} while countries’ strategic plans should be approved by June 2022. After this date the Greek strategic plan could be analysed in order to identify which eco schemes proposed could be put forward as part of our study to encourage farmers to participate in the deployment of NbS interventions. An example could be incentivising farmers to allow some of their agricultural land to flood.

The EU has marked a clear roadmap in relation to both mitigation and adaptation to climate change. In terms of mitigation, the main frame is the “Fit for 55” package (European Council, 2021), whereas adaptation is framed by the EU Adaptation Strategy (2021). For Greece in relation to mitigation,


\textsuperscript{62} “Eco schemes are a part of the Common Agricultural Policy (“CAP”) reform to be implemented from 2023. They are a new “instrument designed to reward” farmers who decide to “go one step further in terms of environmental care and climate action.” (EU Commission, 2021). They must be included in each country’s strategic plan, but their adoption by farmers is voluntary […]”

according to the latest environmental report\textsuperscript{64}, the national target under the EU Effort Sharing Decision is to reduce emissions by 4% compared to 2005. For 2030, Greece’s national target under the Effort Sharing Regulation will be to reduce emissions by 16% compared to 2005. According to its latest projections, Greece is expected to overachieve its 2020 target by 18% (-22\% vs a target of -4\%) and its 2030 target by 7\%.

According to the same report, “Greece adopted its National Adaptation Strategy (NAS) by law in 2016. The Greek NAS is an overarching policy document, which defines the goals, principles and priorities for adaptation. The Greek NAS also lists potential adaptation measures and actions for fifteen (15) environmental and socio-economic sectors that are likely to be significantly affected by climate change including biodiversity and ecosystems, agriculture and food security, forestry, fisheries, water resources, tourism, transport, and insurance”\textsuperscript{65}.

\section*{3.1.5. Protected areas policy}

The EU approved its Biodiversity Strategy as part of the Green Deal, setting ambitious targets for net recovery of biodiversity. This reinforces the existing regulatory framework around NATURA 2000 sites from the Habitats and the birds directive and the designation of Sites of Community Importance (SCIs) and Special Protection Areas (SPAs). According to the report by Mahleras\textsuperscript{66}, there are “twelve protected areas in the Pineios basin” according to the definitions of Article 6 and Appendix IV of the Water Framework Directive 2000/60/EC. These are: two SPA and ten SCI (Areas designated for the protection of habitats or species where the maintenance or improvement of the status of water is an important factor in their protection). Linked to the protected areas policy are also the requirements discussed under the WFD above concerning the objective of achieving good ecological status.

According to the latest environment report for Greece\textsuperscript{67} the country approved its national biodiversity strategy in 2014. By 2019, Greece had designated 446 Natura 2000 sites, including 265 sites of Community importance (SCIs) under the Habitats Directive and 207 Special Protection Areas (SPAs) under the Birds Directive. These sites cover 27.4\% of the national land area of Greece (the EU average being 18.2\%), and a significant proportion of its marine area. The areas containing Natura 2000 sites concerned by the Habitats and Birds Directives in the Trikala and Karditsa regions can be seen in Figure 3-4\textsuperscript{68}.


\textsuperscript{65} EC, 2019


\textsuperscript{67} EC, 2019

\textsuperscript{68} Source: European Environment Agency, 2021
3.2. Roles and responsibilities for flood risk management

In terms of the framework for mapping institutional roles and responsibilities, Table 3-2\(^{69}\) shows the key actors for the different aspects. Roles and responsibilities for flood risk management and institutional arrangements are identified. Several stakeholders of institutions at various governance levels are likely to be involved in the decisions relating to NbS implementation. The following table recaps which institution is responsible in which stage of the decision making process, and it shows that a variety of actors and institutions whose responsibilities sometimes overlap would need to be consulted. This complexity might give rise to challenges in the implementation and management of NbS interventions. Another difficulty lies in the fact that there is a tendency in current plans to favour the planning of grey infrastructure such as dams. A more detailed analysis of each institution's responsibilities and a list of organisations responsible for the various flood risk reduction related activities is presented in Annex 2.

\(^{69}\) Source: Situation analysis, 2021
<table>
<thead>
<tr>
<th>Role</th>
<th>Policy making</th>
<th>Policy Implementation</th>
<th>Investment</th>
<th>Operational management</th>
<th>Regulation and enforcement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Priority setting</td>
<td>Strategic planning</td>
<td>Data &amp; info management</td>
<td>Capacity development</td>
<td>Investment planning</td>
</tr>
<tr>
<td>General Secretariat for Civil Protection of Greece</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ministry of Infrastructure and Transport, General Secretariat of Infrastructure, Directorate General for Natural Disaster Recovery</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ministry of Environment, Special Secretariat for Water</td>
<td></td>
<td></td>
<td>✔</td>
<td></td>
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<tr>
<td>Natural Environment and Climate Change Agency</td>
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<tr>
<td>Bank of Greece, Climate Change Impacts Study Committee (CCISC)</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>National Water Committee</td>
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<td></td>
<td></td>
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<tr>
<td>National Water Council</td>
<td></td>
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<tr>
<td>Water Council of the Decentralised Administration</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Directorate of Thessaly (Decentralised Administration of Central Greece)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decentralised Administration of Thessaly and Central Greece, Directorate of Civil Protection</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policy making</td>
<td>Policy Implementation</td>
<td>Investment</td>
<td>Operational management</td>
<td>Regulation and enforcement</td>
<td></td>
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<tr>
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<td></td>
</tr>
<tr>
<td>Priority setting</td>
<td>Strategic planning</td>
<td>Data &amp; info management</td>
<td>Capacity development</td>
<td>Investment planning</td>
<td>Service delivery</td>
</tr>
<tr>
<td>Decentralised Administration of Central Greece, Forests Directorate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decentralised Administration of Central Greece, Directorate of Rural Affairs of Thessaly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decentralised Administration of Central Greece, Directorate of Environment and Spatial Planning of Thessaly</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region of Thessaly, Directorate of Environment and Spatial Planning</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region of Thessaly, Directorate of Environment and Spatial Planning, Department of Environment</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region of Thessaly, Directorate of Technical Works</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
3.3. Stakeholders and potential beneficiaries

Table 3-3 summarises the main actors identified in a process of stakeholder mapping, in relation to ecosystem services, their influence in relation to flood risk management, and their willingness to cooperate. These identified actors would need to be further consulted to establish a more detailed and harmonised plan in the next phases (e.g., feasibility, design, execution).

Table 3-5 shows that in addition to flood risk reduction which is the main concern for all stakeholders involved, NbS interventions bring many additional benefits which are relevant for most stakeholders. Although a strong political will to adopt NbS for flood risk reduction has been perceived during the interviews with local municipalities and the workshop in Trikala, these multiple benefits are key to mention when actors are approached in the subsequent steps of the study, so they can recognise which are their interests in participating in an NbS implementation programme.

Table 3-3. List of stakeholders and evaluation of various criteria

<table>
<thead>
<tr>
<th>Stakeholder Description</th>
<th>(Ecosystem) Services</th>
<th>Watershed Management Influence</th>
<th>Willingness to Cooperate (scale: 1 – 5 with 5 being the highest)</th>
<th>Funding Potential Direct vs In-kind</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipalities</td>
<td>Flood risk reduction</td>
<td>Low</td>
<td>3-5</td>
<td>Low - Medium</td>
</tr>
<tr>
<td>Region of Thessaly</td>
<td>Flood risk reduction</td>
<td>High</td>
<td>1-2</td>
<td>High</td>
</tr>
<tr>
<td>Decentralised Authority</td>
<td>Flood risk reduction</td>
<td>High</td>
<td>4</td>
<td>High</td>
</tr>
<tr>
<td>Ministries</td>
<td>Flood risk reduction</td>
<td>High</td>
<td>4-5</td>
<td>High</td>
</tr>
<tr>
<td>Farmers</td>
<td>Recharge of water aquifers &amp; flood risk reduction, nutrient transfer</td>
<td>High</td>
<td>2-4</td>
<td>Medium - Low</td>
</tr>
<tr>
<td>NGOs</td>
<td>Biodiversity</td>
<td>Low</td>
<td>5</td>
<td>Medium</td>
</tr>
<tr>
<td>SMEs</td>
<td>Flood risk reduction</td>
<td>Medium</td>
<td>4</td>
<td>Medium - High</td>
</tr>
<tr>
<td>Development Banks</td>
<td>Flood risk reduction</td>
<td>Low</td>
<td>5</td>
<td>High</td>
</tr>
</tbody>
</table>

70 The qualitative assessment was made as part of a collective exercise during the TNC course which included all authors of this report as well as the EIB.
Table 3-4. List of stakeholders and expected associated primary benefit and other benefits of NbS

<table>
<thead>
<tr>
<th>Beneficiaries</th>
<th>Primary Benefit</th>
<th>Other benefits</th>
<th>Resourcing methods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flood risk reduction</td>
<td>Biodiversity</td>
<td>Surface water availability</td>
</tr>
<tr>
<td>Municipalities</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Region of Thessaly</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Decentralised Authority</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Ministries</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Farmers</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>NGO’s</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>SME’s</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Development Banks</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Insurance Companies</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
4. PROPOSED NATURE-BASED SOLUTIONS INTERVENTIONS

Summary box

- Proposed NbS Interventions in selected seven sub-basins (out of 11) of the Pineios river basin included river restoration, floodplain restoration & management, wetland restoration & management, creation of basins, ponds and lakes, and restoration of natural infiltration through small-scale water retention measures, as well as actions for improving the natural condition of rivers, such as removal of dams and longitudinal barriers. Lake Plastira, although not in Pineios river basin, has been included in the proposed areas, all its water is being transferred to the Thessaly plain for irrigation and water supply.
- Proposed NbS interventions are expected to deliver the following benefits: flood risk reduction, aquifer recharge, surface water availability, biodiversity enhancement and provision of recreational opportunities (e.g. hiking trails along the river, birdwatching).
- NbS benefits and their magnitude will depend on the scale, unique design and composition of each specific intervention (e.g. shape, type of vegetation, soil and anorganic materials such as rocks and gravel, specific location within the river basin).
- A retention capacity of 17 million m³ of volume would need to be created to effectively mitigate a flood event with a return period of 50 years for Ano Pineios sub-basin.

This chapter will focus on describing the NbS interventions in selected sub-basins of Pineios River Basin. As described in Chapter 1, the main objective of the study is to conduct a preliminary assessment of the feasibility of Nature-based Solutions (NbS) and their ability to deliver flood risk reduction services in the Pineios river basin. However, the proposals were designed to also offer other potential benefits to the local community, such as the provision of forests with rich species composition (e.g. songbirds, butterflies) in close vicinity to cities for people to enjoy, water availability and aquifer recharge to conserve water as a resource for the local communities and industries, recreational opportunities for people such as trails for hiking and running (see Figure 1-1) in order to address other needs of the local communities.

The proposals developed in the following sections of this chapter have been made by processing information derived from in-person interviews with local and regional stakeholders, but also by using information such as:

- Historical data about the existence of floodplains and wetlands, before the extensive land transformation in the 1940s and the 1970s;
- Aerial imagery of the land cover, using a comparative analysis to locate the land use changes, especially to the river courses and the existence of floodplains and wetlands;
- Studies and plans, such as the Flood Risk Management Plan (FRMP) of Thessaly; and
- The morphology and the inclination of the territory.
4.1. Overview of proposed NbS portfolio per sub-basin

According to the FRMP, the Pineios Basin consists of eleven sub-basins in western Thessaly. However, for the needs of this study two changes are proposed (Table 4-1):

- The Lithaios and Agiamonionis (referred to as "Dytiki koiti Trikalon" in the FRMP) rivers are treated as one system, as the overflow of the two rivers can impact Trikala city. In the FRMP, Agiamoniotis is treated as a single system, while Lithaios is grouped with the Neochoritis river basin, although the later flows much further east (Figure 4.1).
- Plastira Lake (also referred to as Limni Plastira, its Greek name) is not located in the Pineios river basin. However, the discussions that took place in the Trikala workshop have indicated that, as all the water from the lake is directed to Thessaly, special attention should be given to restore its capacity.

This study includes a proposal for seven sub-basins which are part of the Pineios Basin (Enipeas, Sofaditis, Kalentzis, Pamisos, Portaikos, Lithaios-Agiamoniotis & Ano Pineios sub-basins), while proposals have also been made for Limni Plastira. For the needs of this pre-feasibility phase, the study of these eight areas has been considered sufficient, while the remaining four sub-basins (Farsaliotis, Megas, Neochoritis, Kentrikos Pineios) can be studied in the following phases (e.g. feasibility phase).

### Table 4-1. List of sub-basins in western Thessaly

<table>
<thead>
<tr>
<th>Sub-basins</th>
<th>Code</th>
<th>Area size (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enipeas</td>
<td>K1</td>
<td>1140,5</td>
</tr>
<tr>
<td>Farsaliotis</td>
<td>K2</td>
<td>718,9</td>
</tr>
<tr>
<td>Sofaditis</td>
<td>K3</td>
<td>648,1</td>
</tr>
<tr>
<td>Kalentzis</td>
<td>K4</td>
<td>653,8</td>
</tr>
<tr>
<td>Megas</td>
<td>K5</td>
<td>236,1</td>
</tr>
<tr>
<td>Pamisos</td>
<td>K6</td>
<td>247,7</td>
</tr>
<tr>
<td>Limni Plastira*</td>
<td>K7</td>
<td>-</td>
</tr>
<tr>
<td>Portaikos</td>
<td>T1</td>
<td>301,7</td>
</tr>
<tr>
<td>Lithaios-Agiamoniotis</td>
<td>T2</td>
<td>395,5</td>
</tr>
<tr>
<td>Neochoritis</td>
<td>T3</td>
<td>445,6</td>
</tr>
<tr>
<td>Ano Pineios</td>
<td>T4</td>
<td>1130,2</td>
</tr>
<tr>
<td>Kentrikos Pineios</td>
<td>T5</td>
<td>143,5</td>
</tr>
</tbody>
</table>

* Lake Plastira is not included in the FRMP. More info is given in the text.
Depending the level of available information on the sub-basins, actions proposed in the following chapters may have a different level of detail. As an example, the Kalentzis river basin includes a relatively increased amount of information while Enipeas' actions are vaguer and they rather consist of more general suggestions. These actions should be specified in more detail in the feasibility study.

Each of the following sub-chapters contains a map with all the proposed actions and a table that provides more information on these interventions. The interventions were selected from Table 1-3 (chapter 1), which provides an overview of the most common NbS to deliver flood risk reduction services in the context of riverine ecosystems. The size of the polygons in the map (e.g. orange circles) does not indicate the size or the significance of the proposed interventions. More information on each area/sub-basin (e.g. main cities affected by floods, a description of the area and the hydrological conditions, etc.) is given in Annex 3.

Finally, at the end of each sub-chapter a qualitative evaluation of the benefits per NbS intervention is given, following the scale given in Table 4-2.

![Figure 4-1. Sub-basins within the Pineios basin](image)

**Table 4-2. Expected magnitude of benefits created by NbS**

<table>
<thead>
<tr>
<th>Legend</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected magnitude of benefits created by NbS</td>
<td></td>
<td>+</td>
<td>++</td>
</tr>
</tbody>
</table>
4.1.1. Enipeas river basin (K1)

Main objective

✓ Mitigate the flood risk for the settlements in the lower part of the Enipeas river

Table 4-3. Interventions proposed for mitigating flood risk in lower Enipeas Basin

<table>
<thead>
<tr>
<th>INTERVENTIONS PROPOSED (K1.1 – K1.7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K1.1-K1.2 --- River restoration, Removal of dams and other longitudinal barriers, Forest riparian buffers</td>
</tr>
</tbody>
</table>

Restoration of the old and new courses of the Enipeas river is proposed as a significant intervention to be explored. Restoration includes widening of the rivers and removal of any longitudinal barriers (it is known that soil dams are constructed each year to store water). This action is strongly related to the restoration of floodplains and wetlands (actions K1.3-K1.5), while interventions should also be explored in the upper part of Enipeas, which belongs to another administrative division. A forest riparian buffer should also be established, as it would serve as a protection zone against erosion while also providing a habitat for biodiversity.
**K1.3-K1.5 --- Floodplain restoration and management, wetland restoration and management**

Three areas are proposed to be restored as floodplains. Areas K1.3 & K1.5 have a high probability of getting flooded, as indicated in the FRMP of Thessaly, while area K1.4 used to be a floodplain in the 1940s, as the Ofios stream ran from this area. In regard to K1.5, this area would also serve as a floodplain of Sofaditis River (K3). Alternatively, area K1.5 could also be transformed into a wetland that would be fed by the Enipeas, Farsaliotis and Sofaditis rivers.

**K1.6 --- Basins, ponds and lakes**

The connection of the Ilias reservoir with the Enipeas river, to be used as water retention pond in case of extreme weather events, should be explored.

**K1.7-K1.8 --- Restoration of natural infiltration**

During winter and spring, the overflow of Enipeas River is directed towards old boreholes close to Orfana village for natural infiltration and groundwater recharge (K1.8). As a result, the level of the groundwater has risen to -80m, while in other areas of the Thessaly plain the level is down to -380m. A similar process was proposed at the Trikala workshop for area K1.7. The restoration of natural groundwater infiltration allows the reduction of surface runoff and improves the status of groundwater aquifers, improves water quality and availability, and thus reduces economic costs for the region and sectors that depend on water.

<table>
<thead>
<tr>
<th>Areas</th>
<th>NbS Interventions</th>
<th>Expected magnitude of key services (benefits)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flood risk reduction</td>
<td>Aquifer recharge</td>
</tr>
<tr>
<td>K1.1-K1.2</td>
<td>River restoration</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Removal of dams and other longitudinal barriers</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Forest riparian buffers</td>
<td>++</td>
</tr>
<tr>
<td>K1.3-K1.5</td>
<td>Floodplain restoration &amp; management</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Wetland restoration &amp; management</td>
<td>++</td>
</tr>
<tr>
<td>K1.6</td>
<td>Basins, ponds and lakes</td>
<td>+</td>
</tr>
<tr>
<td>K1.7-K1.8</td>
<td>Restoration of natural infiltration</td>
<td>+</td>
</tr>
</tbody>
</table>

Table 4-4. Evaluation of benefits per NbS intervention in Enipeas basin
4.1.2. Sofaditis river basin (K3)

Main objective

- Reduce the flood risk for Sofades, the downstream villages and infrastructure in the lower part of the Sofaditis basin.

Figure 4-3. List of proposed interventions for mitigating flood risk within the Sofaditis river basin
Table 4-5. Interventions proposed for mitigating flood risk in Sofaditis Basin

<table>
<thead>
<tr>
<th>INTERVENTIONS PROPOSED (K2.1 – K2.4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>K3.1-K3.4 --- River restoration, Re-meandering, Removal of dams and other longitudinal barriers, Forest riparian buffers</strong></td>
</tr>
</tbody>
</table>

As regards action K3.1 (Sofaditis from Kedros village to E65; green line), to a large extent the width of the riverbed seems to be sufficient. Point interventions are proposed to allow water, in extreme events, to spread along the riverbed. Possible meandering is recommended as well, while a forest buffer should also be established from Kedros to Filia village, as it would serve as a protection zone against erosion and provide habitat for biodiversity. Special attention should be given to the junction of Sofaditis with E65, as the planning of the new national road does not seem to take into account the increased flooding risk in the area.

From E65 up to Sofades, the width of Sofaditis is significantly smaller (<100m), thus creating a bottleneck and contributing to floods. The widening of the river (K3.2; yellow line) is recommended, while the connection of the river with the floodplain should also be explored (action K3.5).

Similarly, it is recommended that the section of Sofaditis from the railway track to the end of Moscholouri village be widened (K3.3; red line). The river at this point remains very narrow (~50m), thus failing to drain the water without creating flood incidents. The connection of this section with the floodplain (action K3.6) should be explored, while the development of a riparian forest should also be considered as a potential solution. Actions K3.2, K3.3, K3.5 and K3.6 are expected to significantly reduce the risk for Sofades.

The area where Sofaditis meets Rogozinos river (south of Markos village) and the part close to the junction with Enipeas river are also prone to flooding. This river section is channelised, as it has resulted from the diversion of other smaller rivers and streams formerly in the area. The widening of this part of Sofaditis (actions K3.4; purple line) and the connection with the floodplain/wetland proposed in Enipes basin (§4.2.1, action K1.5) is expected to reduce floods in the area.

| **K3.5-K3.8 --- Floodplain restoration and management, Basins, ponds, and lakes** |

The purpose of actions K3.5 & K3.6 is to mitigate the flood risk for Sofades by creating a complementary to the river restoration intervention. Action K3.5 should have the ability to retain the water before reaching Sofades, while action K3.6 will protect the city from backwater effects. Both of these actions will contribute to the reduction of floods in the lower part of Sofaditis, from Markos up to the junction with Enipeas.

Intervention K3.7, west of Mataragka village, focuses on retaining some water and mitigating the flood risk downstream of Markos, while action K3.8 is located in Rogozinos river, on old floodplains as indicated on the 1944 and the 1945 National Cadastre maps. The flood risk for this area is lower. However, this intervention is expected to retain the water from this tributary and contribute further to flood mitigation in the lower part of Sofaditis.

| **K3.9 --- Restoration of natural infiltration** |

In the upper, mountainous part of Sofaditis and its tributaries, the construction of multiple small stone dams (~0.5m height) is proposed. This measure is in accordance with proposed measure EL-08-31-08 of the Thessaly flood risk management plan. This is a relatively inexpensive action (in Kythera and Paros islands, where this solution was implemented, the cost was ~700 €/dam) with multiple benefits (retaining water before creating flood problem in the plain, erosion control, aquifer recharge, water ponds as biodiversity spots, etc.).

| **K3.10 --- Wetland restoration and management** |

Although not located in the administrative division of Karditsa (in western Thessaly), the restoration of Lake Xiniada should also be explored. Lake Xiniada, located in the Omvriaki Plateau, covered an area of 3160 ha (with a maximum depth of 4 metres) before it was drained during the period 1936-1942 to obtain agricultural land. The last few years, the discussion for the restoration of 2600 ha has been
opened, as soil fertility in the former lake area has gradually deteriorated and farming provides less than the expected economic benefits. A restoration of the lake would not contribute directly to addressing flooding challenges in western Thessaly, but would be expected to improve the quality of water flowing to the Thessaly plain.

Table 4-6. Evaluation of benefits per NbS intervention in Sofaditis basin

<table>
<thead>
<tr>
<th>Areas</th>
<th>NbS Interventions</th>
<th>Expected magnitude of key services (benefits)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Flood risk reduction</td>
</tr>
<tr>
<td>K3.1-K3.4</td>
<td>River restoration</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Re-meandering</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Removal of dams and other longitudinal barriers</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Forest riparian buffers</td>
<td>++</td>
</tr>
<tr>
<td>K3.5-K3.8</td>
<td>Floodplain restoration &amp; management</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Basins, ponds and lakes</td>
<td>++</td>
</tr>
<tr>
<td>K3.9</td>
<td>Restoration of natural infiltration</td>
<td>+</td>
</tr>
<tr>
<td>K3.10</td>
<td>Wetland restoration &amp; management</td>
<td></td>
</tr>
</tbody>
</table>
4.1.3. Kalentzis river basin (K4)

Main objective

- Reduce the flood in Karditsa city and the villages in the lower course of Kalentzis.

Figure 4-4. List of proposed interventions for mitigating flood risk within the Kalentzis river basin
### INTERVENTIONS PROPOSED (K.4.1 – K.4.13)

#### K.4.1-K.4.5 --- Floodplain restoration and management, Basins, ponds, and lakes

The creation of four to six floodplain/retention ponds close to the three main rivers, upstream of Karditsa, is proposed as a solution for providing emergency storage areas in case of high rainfalls and reducing pressure downstream.

One floodplain/retention pond is proposed to be created on the western part of Kalentzis river (K.4.1), between the villages Kallifoni, Zaimi & Ptelopoula. This area should accept the waters from Kalentzis and Lipsimos. Two more floodplains are proposed to store the extra water of Karampalis, one to the north of Agiopigi village (K.4.2) and one attached to Karampalis, between the villages of Kallithiro and Rousso (K.4.3). Opposite to Kalentzis and Karambalis, the Gavras river does not maintain its original course and a significant part of it has been channelised. Ideally, the widening of the riverbed of Gavras and the creation of a forest riparian buffer should be considered. As an alternative, an additional floodplain/retention pond is proposed where the old Gavras riverbed meets the channel (north of village Georgiko; K.4.4). These actions should be combined with measure K.4.10. Finally, another retention pond should be explored in the area between Franko and Paleoklisi (K.4.5), in order to store the water coming from Gavras stream.

#### K.4.6-K.4.8 --- River restoration, Re-meandering, Removal of dams and other longitudinal barriers, Forest riparian buffers

Along with actions K.4.1-K.4.5, the widening of the rivers Karambalis and Kalentzis should also be explored. The riverbed of both rivers is reduced at some point creating a bottleneck and an increased risk of flooding. Regarding Karambalis, this should take place from Roussol village up to the joining of Karambalis with Kalentzis (K.4.7). The upper part of Karambalis (until it joins Gavras) crosses rural land; however, the restoration of the remaining section is more challenging due to existing infrastructure networks. Similarly, the widening of the upper part of the Kalentzis riverbed (K.4.6; from Melissa village up to the junction with Karambalis) should be explored. Again, the most challenging part is close to the national road Karditsa-Volos due to existing buildings and other activities. In regard to the lower course of Kalentzis (K.4.8), the riverbed is very well defined between embankments. However, although the width of the first part is sufficient (~200m), after Myrina village it gets significantly narrower (<100m), creating a bottleneck and contributing to the increased flooding problem of the area defined by the villages Myrina, Makrychori, Koskinas, Metamorphosi, Psathohori and the river Lipsimos. The widening of the river should be explored while the restoration of the floodplain in the lower part of Kalentzis could also contribute to the mitigation of flood risk (action K.4.9).

#### K.4.9 --- Floodplain restoration and management (lower course of Kalentzis River)

The restoration of the floodplain in the area defined by the Lipsimos and Kalentzis Rivers and Makrchori and Metamorphosi villages is proposed. This area used to be a seasonal flood plain according to the 1943 German map and the 1944 map from the British War Office and U.S. Army Map Service, while also it’s included in the FRMP as a high potential area for flooding. This is further confirmed by the fact that this area was flooded during the 2018 and 2020 (Ianos) events. Specific works should be carried out to achieve these actions: removal of embankments, connection of the Kalentzis and Lipsinos rivers with the flood plain, etc.

#### K.4.10 --- Restoration of natural infiltration

In the upper, mountainous part of rivers Gavras, Karambalis and Kalentzis and their tributaries, the construction of many small stone dams (~0.5m height) is proposed. This measure is in accordance with proposed measure EL-08-31-08 of the Thessaly FRMP.

---

**Table 4-7. Interventions proposed for mitigating flood risk in Kalentzis Basin**
### Table 4-8. Evaluation of benefits per NbS intervention in Kalentzis basin

<table>
<thead>
<tr>
<th>Areas</th>
<th>NbS Interventions</th>
<th>Expected magnitude of key services (benefits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K4.1-K4.5</td>
<td>Floodplain restoration &amp; management</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Basins, ponds and lakes</td>
<td>++</td>
</tr>
<tr>
<td>K4.6-K4.8</td>
<td>River restoration</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Re-meandering</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Removal of dams and other longitudinal barriers</td>
<td>+</td>
</tr>
<tr>
<td>K4.9</td>
<td>Floodplain restoration and management</td>
<td>++</td>
</tr>
<tr>
<td>K4.10</td>
<td>Restoration of natural infiltration</td>
<td>+</td>
</tr>
</tbody>
</table>
4.1.4. **Pamisos river basin (K6)**

**Main objective**

- Reduce the flood risk for Mouzaki
- Mitigate the flood risk for settlements in the lower part of Pamisos river (Megala Kalyvia, Agnantero, Palaiochori)

<table>
<thead>
<tr>
<th>INTERVENTIONS PROPOSED (K6.1 – K6.3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>K6.1 --- River restoration, Natural bank stabilisation, Elimination of riverbank protection, Forest riparian buffers</strong></td>
</tr>
<tr>
<td>The proposed actions include the restoration of the Pamisos riverbed in 10-12 locations. The most important interventions should be made in the part of the river that crosses the city of Mouzaki (removing buildings and other infrastructures, widening the riverbed, removing riverbank protection and implementing natural bank stabilisation), as the width of the Pamisos riverbed in that section has been largely reduced and the river confined between embankments (Figure 4-5). The development of a riparian zone should also be examined. This zone would be a buffer zone, protecting the riverbed from erosion and providing habitat for biodiversity and spaces for recreation.</td>
</tr>
<tr>
<td><strong>K6.2 --- River restoration, Forest riparian buffers</strong></td>
</tr>
<tr>
<td>The restoration of the lower Pamisos section, from Magoula up to Pineios, should be explored. Embankments should be removed, the bed should be widened and the river should be connected to the floodplain, both to the west (towards Megala Kalyvia) and the east (Agnantero), allowing the smaller streams running perpendicular to Pamisos to flow freely. A forest riparian buffer should also be established, as it would contribute to mitigating flood risks and serve as a protection zone against erosion, while also providing a habitat for biodiversity.</td>
</tr>
<tr>
<td><strong>K6.3 --- Floodplain restoration and management</strong></td>
</tr>
<tr>
<td>In coordination with action K6.2, the restoration of the floodplain on both sides of the lower part of Pamisos is proposed. This intervention is expected to reduce the impacts from the frequent flooding that occurs in the area.</td>
</tr>
</tbody>
</table>

---

71 For more information, see Annex 4, Pamisos factsheet.
### Table 4-10. Evaluation of benefits per NbS intervention in Pamisos basin

<table>
<thead>
<tr>
<th>Areas</th>
<th>NbS Interventions</th>
<th>Expected magnitude of key services (benefits)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Flood risk reduction</td>
</tr>
<tr>
<td>K6.1</td>
<td>River restoration</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Elimination of riverbank protection</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Natural bank stabilisation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forest riparian buffers</td>
<td></td>
</tr>
<tr>
<td>K6.2</td>
<td>River restoration</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Forest riparian buffers</td>
<td></td>
</tr>
<tr>
<td>K6.3</td>
<td>Floodplain restoration and management</td>
<td>++</td>
</tr>
</tbody>
</table>

**Legend**
- Pamisos River
- Restoration of Pamisos
- Small rivers and streams
- Pineios River
- Megas River
- Floodplain
- Interventions in Mouzaki

**Figure 4-6.** List of proposed interventions for mitigating flood risk within Pamisos river basin
4.1.5. Lake Plastira (K7)

Main objective

- Mapping and surveying the bottom of the lake to provide a better knowledge on the decrease of the lake's effective volume.

<table>
<thead>
<tr>
<th>INTERVENTIONS PROPOSED (K7.1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K7.1 --- Hydrographic survey</td>
</tr>
</tbody>
</table>

Mapping and surveying the bottom of the lake will be implemented as part of a water depth study, carried out by the Hellenic Navy. The outcomes of this study will determine the work that needs to be done for the removal of sediments and debris from Lake Plastira.

<table>
<thead>
<tr>
<th>Areas</th>
<th>Actions</th>
<th>Expected magnitude of key services (benefits)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Flood risk reduction</td>
</tr>
<tr>
<td>K7.1</td>
<td>Hydrographic survey</td>
<td>++</td>
</tr>
</tbody>
</table>
4.1.6. Portaikos river basin (T1)

Main objective

- Reduce the flood risk for Pyli.
- Mitigate the flood risk for settlements in the lower part of the sub-basin of Portaikos.

Table 4-13. Interventions proposed for mitigating flood risk in Portaikos Basin (continued)

<table>
<thead>
<tr>
<th>INTERVENTIONS PROPOSED (T1.1 – T1.6)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>T1.1 --- River restoration, Floodplain restoration and management, Forest riparian buffers</strong></td>
</tr>
</tbody>
</table>

The proposed actions include the restoration of the Portaikos riverbed in three specific sites, near the city of Pyli. As seen in Figure 4-8, the width of the river has been reduced and the riverbed has been channelised since 1945-1960. As a result, the potential of damages in Pyli in case of high rainfall has been increased. Restoration should also include the creation of a riparian forest as a buffer zone to

Figure 4-7. List of proposed interventions for mitigating flood risk within Portaikos river basin

Legend

- Main rivers in the area
- Riverbed restoration
- Adjacent areas to rivers
- Floodplains
- Interventions in Pyli
ensure protection from erosion, provide habitat for biodiversity and create spaces for recreation. In addition to the proposed interventions, other measures should also be explored upstream of Pyli, based on the 1945-1960 aerial photos of the Greek Cadastre.

Table 4-14. Actions proposed for mitigating flood risk in Portaikos Basin

<table>
<thead>
<tr>
<th>T1.2 --- Floodplain restoration and management, Forest riparian buffers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor interventions should be made in specific areas downstream of Pyli, aiming at retaining water and preventing it from reaching the lower part of the sub-basin, which is prone to flood rapidly. The proposed interventions are mainly on public land and include the translocation of the embankments, the connection of the river with the adjacent land and the creation of a riparian forest buffer.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>T1.3 --- River restoration</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Portaikos riverbed becomes significantly narrower downstream of Lili village, although it joins with rivers Bedenis and Anapodos. The proposed interventions include the widening of the riverbed from Lili village up to the junction of Portaikos with Pineios (~3,1km). This measure, along with action T1.6, is expected to reduce the flood risk in the lower part of the sub-basin.</td>
</tr>
</tbody>
</table>
**T1.4 --- River restoration**

The widening of rivers Bedenis and Anapodos is proposed. Although their width hasn't been changed since the 1940s, because of the expected increase of extreme events as a result of climate change and the high potential of flooding risk in the lower part of Portaikos sub-basin, this measure should be explored. In both cases, the rivers run off through agricultural land.

**T1.5 --- Floodplain restoration and management, Forest riparian buffers**

The area around villages Matsoukiotika and Valtino is also a high-risk area for floods according to the FRMP. The proposed measure focuses on widening the riverbed of Aforesmeno river near Dendrochori and Valtino (~2.6km) and creating a floodplain that will also host a riparian buffer zone for protection and recreation. Moreover, the transformation of a small area close to Matsoukiotika into a floodplain is also proposed.

**T1.6 --- Floodplain restoration and management, wetland restoration and management**

The creation of four to six floodplain/wetlands/retention ponds is proposed as a solution to reduce the flood risk in the lower part of the sub-basin. These actions will work in conjunction with the other measures already proposed. All of these areas coincide with historical flood plains (as depicted in the 1944 maps from the British War Office and U.S. Army Map Service; see Annex 3, sheet: sub-basin Portaikos) that have been transformed into agricultural land.

---

**Table 4-14. Evaluation of benefits per NbS intervention in Portaikos basin**

<table>
<thead>
<tr>
<th>Areas</th>
<th>NbS Interventions</th>
<th>Expected magnitude of key services (benefits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1.1</td>
<td>River restoration</td>
<td>Flood risk reduction ++, Aquifer recharge +, Surface water availability +, Biodiversity ++, Recreation ++</td>
</tr>
<tr>
<td></td>
<td>Floodplain restoration and management</td>
<td>++, +, +, ++, +</td>
</tr>
<tr>
<td></td>
<td>Forest riparian buffers</td>
<td>+, ++, +, +</td>
</tr>
<tr>
<td>T1.2</td>
<td>Floodplain restoration and management</td>
<td>++, +, +, ++, +</td>
</tr>
<tr>
<td></td>
<td>Forest riparian buffers</td>
<td>+, ++, +, +</td>
</tr>
<tr>
<td>T1.3</td>
<td>River restoration</td>
<td>+, +, +, +, +</td>
</tr>
<tr>
<td>T1.4</td>
<td>River restoration</td>
<td>++, +, +, +, +</td>
</tr>
<tr>
<td>T1.5</td>
<td>Floodplain restoration and management</td>
<td>++, +, +, ++, ++</td>
</tr>
<tr>
<td></td>
<td>Forest riparian buffers</td>
<td>+, ++, +, +, ++</td>
</tr>
<tr>
<td>T1.6</td>
<td>Floodplain restoration and management</td>
<td>++, ++, +, +, +</td>
</tr>
<tr>
<td></td>
<td>Wetland restoration and management</td>
<td>++, ++, +, +, +</td>
</tr>
</tbody>
</table>
4.1.7. Lithaios-Agiamoniotis river basin (T2)

Main objective

- Reduce the flood risk for Trikala city, protect local communities and infrastructure (e.g., bridges, roads, electricity transmission networks).
- Mitigate the flood risk to the areas downstream of Trikala.

<table>
<thead>
<tr>
<th>INTERVENTIONS PROPOSED (T2.1 – T2.6)</th>
</tr>
</thead>
</table>

**T2.1-T2.2 --- River restoration, Forest riparian buffers**

The old riverbed of Lithaios is no longer in use (T2.1), as the river was diverted decades ago. The length of the old riverbed from Trikala to Klokotos village is 32km, while the mean width of the riverbed is 14 metres. The old riverbed can be used as a very long natural "reservoir" (32 x 0.014 km² ≈ 45ha), both to mitigate the flooding risk from backwater effect from Pineios River and to reduce the risk from the Lithaios water basin. The widening of the old riverbed could be explored, while the creation of a forest riparian buffer should also be among the main objectives of this action. Special attention should be given to the junction of Lithaios with E65, as the planning of the new national road...
does not take into account the increased flooding risk in the area.

The restoration of the old Milavlako stream (T2.2) is also proposed. The old river is 7.9km long and 10-12 metres wide (7.9 x 0.011 km² ≈ 8.6ha). Similarly to action T2.1, the widening of the river and the creation of a riparian buffer zone should also be explored, while special attention should be given to the junction of Milavlako stream with E65.

**T2.2-T2.4 --- Floodplain restoration and management, Basins, ponds, and lakes**

The creation of four floodplain areas/retention ponds is recommended, two in Agiamoniotis river (T2.2), one in Lithaios river upstream of Trikala (T2.3) and one after Faneromeni, close to Petroporos village (T2.4). Flood risk maps indicate a high probability of floods around the Agiamonioris river, south of the villages Megalo Kefalovryso and Apostoloi. The proposed floodplains/retention ponds will be created on public land, on both tributaries of Agiamonioris, close to those villages. This measure, along with Action T2.5, is expected to reduce flood risk coming from this area. Similarly, as flood risk maps also indicate a high probability floods south of the villages of Raxa and Sotira, a third floodplain/retention pond is proposed between these two villages. Historical maps from 1943 indicate the existence of floodplains in that exact area. Finally, the fourth floodplain/retention pond is proposed to be created close to Petroporos village on previously existing floodplains (according to 1943-1944 maps and 1945 aerial photos provided by the National Cadastre and Mapping Agency of Greece.

**T2.5 --- River restoration (Agiamoniotis), Forest riparian buffers**

As a complementary action to the floodplains of T2.2, the widening of Agiamoniotis river for a length of ~2 km (from Apostoloi village up to the Trikala peripheral road, close to Kipaki village) is recommended. The 1944 map also indicates the presence of a marsh/wetland in that area. Respective interventions should also be explored for a length of about 2.5km, just before the railway track. This action will also benefit biodiversity and allow for recreational activities.

**T2.6 --- Restoration of natural infiltration, Targeted planting for “catching” precipitation**

In the upper, mountainous part of Lithaios river and its tributaries, the construction of many small stone dams (~0.5m height) is proposed. This measure is in accordance with proposed measure EL-08-31-08 of the Thessaly flood risk management plan. The reforestation of the mountains close to the villages of Platanos, Riza and Avra should also be explored.

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<table>
<thead>
<tr>
<th>Areas</th>
<th>NbS Interventions</th>
<th>Expected magnitude of key services (benefits)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Flood risk reduction</td>
</tr>
<tr>
<td>T2.1</td>
<td>River restoration</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Forest riparian buffers</td>
<td></td>
</tr>
<tr>
<td>T2.2-T2.4</td>
<td>Floodplain restoration and management</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Basins, ponds and lakes</td>
<td></td>
</tr>
<tr>
<td>T2.5</td>
<td>River restoration</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Forest riparian buffers</td>
<td></td>
</tr>
<tr>
<td>T2.6</td>
<td>Restoration of natural infiltration</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Targeted planting for ‘catching’ precipitation</td>
<td></td>
</tr>
</tbody>
</table>

---

Table 4-16. Evaluation of benefits per NbS intervention in Kalentzis basin
4.1.8. Ano Pineios river basin (T4)

Main objective

✓ Reduce the flood risk for the settlements of the lower part of the sub-basin.

*Figure 4-10. List of proposed interventions for mitigating flood risk within Ano Pineios river basin*
A more detailed approach has been selected for the area opposite from the other sub-basins of western Thessaly, as an indication of what should be included in the feasibility study. A hydrologic and a hydraulic analysis was conducted\textsuperscript{72} with the use of the relevant tools (HEC-HMS, HEC-RAS), and specific datasets were used in the analysis: a Digital Elevation Model (DEM), provided by the National Cadastre & Mapping Agency S.A., the “CORINE Land Cover” (2018) dataset, and the Intensity Duration Curves (IDF) of nearby located stations, as derived in the course of the Flood Risk Management Plans for Greece by the Ministry of Environment, Energy and Climate Change (SSW-MEECC, 2017) and officially applied in Greece. The approach is explained in detail in Annex 5 and focuses on mitigating the flood risk in a specific part of the sub-basin (the area between Mourgkani, Diava and Kalambaka), while a return period of 50 years is examined. For two different scenarios ($Q_{500}$ and $Q_{700}$, referring to $500\text{m}^3/\text{s}$ and $700\text{m}^3/\text{s}$ as maximum discharge values), it has been found that approximately 6 and 17 million $\text{m}^3$ of runoff volume respectively for each scenario should be retained by the upstream ponds. The selection of the exact location of the ponds should be identified in the feasibility phase, based on of the Digital Elevation Model (DEM). As indicated in the study, a combination of many smaller Nature-based Solutions should be preferred over a bigger concrete dam.

\textit{Table 4-17. Interventions proposed for mitigating flood risk in Ano Pineios Basin}

**INTERVENTIONS PROPOSED (T4.1 – T4.2)**

**T4.1 --- River restoration, Forest riparian buffers**

The proposed actions include several interventions along the riverbeds of the rivers Malakasiotikos, Klinovitikos, Ion (Mourgkanis) and Ano Pineios. In general, as described in Annex 3 (Sub-basin: Ano Pineios), significant changes have been made in the width of the riverbed, as seen from the 1945/1960 aerial photos. In many cases, these interventions are irreversible as they include the urbanisation of the riparian zones, and the use of public land for the construction of national road E65 (near Kalambaka, the riverbed has been reduced from 1300m to 550m). In Malakasiotikos river, the restoration of the riverbed to the extent of its 1945 width is proposed for a distance of ~4.5km along the north part of the river. The initial riparian zone has been transformed into agricultural land, as revealed by the aerial photos of the Greek Cadastre. Fewer interventions are proposed for the Klinovitikos and Ion (Mourgkanis) rivers, aiming to restore the historical riverbed. Since no interventions can be made close to Kalambaka, specific actions should be also taken in the Ano Pineios section (river restoration, forest riparian buffers), as indicated in Figure 4-10.

**T4.2 --- Floodplain restoration and management, wetland restoration and management**

The creation of five to seven floodplain/wetlands/retention ponds is proposed as a solution to reduce the flood risk in the lower part of the sub-basin. These actions will work in conjunction with the restoration of the river in the areas already proposed in intervention T4.1.

\textit{Table 4-18. Evaluation of benefits per NbS intervention in Ano Pineios basin}

<table>
<thead>
<tr>
<th>Areas</th>
<th>NbS Interventions</th>
<th>Expected magnitude of key services (benefits)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Flood risk reduction</td>
</tr>
<tr>
<td>T1.1</td>
<td>River restoration</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Forest riparian buffers</td>
<td></td>
</tr>
<tr>
<td>T1.2</td>
<td>Floodplain restoration and management</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Wetland restoration and management</td>
<td>++</td>
</tr>
</tbody>
</table>

\textsuperscript{72} Baltas, 2022
5. NEXT STEPS

To date, concrete steps have been taken by the project team, the municipalities and local stakeholders to initiate the process in Western Thessaly of identifying and developing of Nature-based Solutions as an effective way to address flood risk and other societal challenges. This collective effort has set the basis: (i) for strengthening the partnership and developing a common understanding of the conditions and requirements for implementing NbS in western Thessaly, and (ii) to start preparing the next steps aiming to design and implement large-scale NbS interventions in the area.

This chapter includes a short description of the steps that have already been taken, and –more importantly– analyses next steps, based on the project team’s experience and the knowledge acquired from the local conditions, but also taking into account the following standards and tools:

1. IUCN Global Standard for NbS\(^{73}\)
2. SuRe® – The Standard for Sustainable and Resilient Infrastructure\(^{74}\)
3. The sustainable asset valuation (SAVi)

As seen in Figure 5-1 (modified from Figure 1.2 to include a step between pre-feasibility and feasibility), a distinctive process has been defined. Each phase contains a number of actions described in the following paragraphs. Less attention has been given to the latest phases of the diagram (e.g. design, execution) as their implementation is strongly depended on the feasibility phase. The actions presented in each phase are, to the extent that this is possible, in chronological order, as can be seen also in Chapter 5.6.

\(^{73}\) It consists of 8 Criteria and 28 Indicators to support users in 1) assessing the extent to which a proposed solution qualifies as an NbS and identifying what actions can be taken to further strengthen the robustness of the intervention, and 2) enabling purposeful design of a solution to adhere to the Criteria and Indicators.

\(^{74}\) SuRe® is a globally applicable Standard for Infrastructure projects. SuRe® can be applied to all Infrastructure sectors. The SuRe® Standard’s objective is to drive the integration of Sustainability and Resilience aspects into Infrastructure development and upgrade by providing guidance and serving as a globally applicable common language tool for Infrastructure project developers, financiers and public sector institutions. The SuRe® Standard also aims to incorporate the rights, needs and context of future generations impacted by the Infrastructure development and any upgrade.
5.1. Pre-feasibility phase (completed)

By finishing and delivering the current pre-feasibility study to the EIB, this phase can be considered as completed. An overview of the actions that have been finalised up until now is outlined below.

- **Nature for Catchments Launchramp (NCL) methodology**
  The methodology was developed by the project team prior to conducting the study. The Nature for Catchments Launchramp (NCL) methodology is a project origination process for Nature-based Solutions (NbS) interventions.

- **Situation analysis**
  A study confirming the viability of NbS interventions from both a technical and a political standpoint (e.g. buy-in from key stakeholders, suitable space and topography to implement NbS projects, etc.).

- **Consultation with local authorities**
  Virtual meetings with all ten municipalities of western Thessaly and subsequent face-to-face meetings with key stakeholders from municipalities, the Region of Thessaly and the Decentralised Administration of Thessaly and Sterea Ellada.

- **Capacity building workshop**
  Capacity building workshop in Trikala boosting local/regional capabilities to assess climate risks and adopt effective solutions, with a focus on NbS. Participants were from municipalities, from the Region of Thessaly, from the Decentralised Administration of Thessaly and Sterea Ellada, and from the Ministry of Environment.

- **Pre-feasibility study**
  A preliminary assessment of the feasibility of Nature-based Solutions and their ability to deliver critical services, including flood risk reduction.

5.2. Preparation for feasibility study

After delivering the pre-feasibility report to EIB, specific steps should be taken to ensure that the local stakeholders understand the actions proposed, while preliminary meetings with the competent ministries are necessary to plan the next steps. Finally, a funding process for the feasibility phase should be addressed.

- **Consultation with local authorities**
  A round of meetings with local stakeholders should be organised, aiming to present the pre-feasibility study and ideally conclude in 1-2 sub-basins for interventions with their consent. Target audience should come from municipalities and regional decision makers.

- **Meeting with competent authorities**
  Following (or in parallel to) the previous step, meetings with the Ministries of Environment, Infrastructure and Civil Protection should be pursued to urge for support of the proposed interventions by the central government and competent authorities.

- **Funding process defined and executed**
  The funding/financing process for implementing the feasibility phase should be defined and all necessary actions (identification of the beneficiary, preparing the contract, etc.) should be made.
5.3. Feasibility phase

The proposed objectives of the feasibility phase are to test whether a specific viable NbS portfolio exists that can achieve outcomes and attract commitments from stakeholders. The inclusion of local communities and affected stakeholders can be considered of high importance. Technical studies, including mapping, hydrological modelling shall be conducted in this phase. In addition to that, the project team suggests to engage with field practitioners to assemble a detailed understanding of the execution and costing realities for implementation scale-up. This phase can create a powerful centralised vision for the stakeholder group and to operationalise the investment plan.

- **Stakeholder mapping**
  Appropriate governance processes are critical in determining the successful outcomes of NbS interventions. Using a robust stakeholder-mapping tool, a stakeholder analysis needs to be carried out in order to identify and engage the full range of people that may be affected by the proposed NbS interventions. The process also needs to identify stakeholders who may be negatively affected and afford opportunities for their empowerment. Also, the rights to, use of and access to land and resources, along with the responsibilities of different stakeholders, will need to be mapped.

- **Grievance or dispute settlement mechanism**
  A grievance or dispute settlement mechanism should be adopted early on, whether it be a formal legal process or an informal non-legal system. This mechanism should have agreed procedures, roles and rules for receiving and adjudicating such disputes. The grievance mechanism should be legitimate, accessible, predictable, equitable, transparent, rights-compatible, adaptively managed and based on engagement and dialogue.

- **First consultation with target audience**
  After the first two steps of the feasibility phase, a first round of meetings with the target audience (e.g. farmers, small businesses affected by floods, and others that have been identified during the stakeholder mapping process) should be organised. During this first meeting, the societal challenge(s) addressed must be clearly understood and documented, while significant input will be acquired in regard to risk identification and management. Finally, this process will set the basis for an inclusive, transparent and empowering governance process.

- **Meeting with relevant authorities**
  In parallel to the meetings with the target audience, meetings with public authorities (ministries, municipalities, regional authorities) should also be planned, aiming to inform them on the process and secure their participation. Human well-being outcomes arising from the NbS will be identified and clear and measurable biodiversity conservation outcomes will be highlighted, while a first discussion on the direct and indirect benefits and costs associated with the NbS, who pays and who benefits, will be carried out.

- **Meeting with stakeholders working in finance & insurance**
  The involvement of insurance institutions such as the Hellenic Agricultural Insurance Organisation (ELGA) and other re-insurance companies (e.g. Swiss Re) should be considered early on in the process. In addition, the project team should plan meetings with other enterprises operating in the region (e.g. Terna). Insurance can improve the financial attractiveness of NbS projects to investors and project owners through better understanding of the risk/return rewards. This is expected to enhance ownership of the approach, reduce the risks of negative unintended consequences and facilitate the overall mainstreaming of NbS into policies and sectors.

- **Establishment of a steering committee**
  The committee shall oversee the work to be done in the next stages (e.g. feasibility stage, design, execution). It shall consist of key Greek experts/institutions (academia, engineering, finance) as well as international experts who can provide guidance and channel NbS-relevant knowledge and tools and deploy their networks to create a successful pilot project in Greece.
• **Hydraulic and Hydrological study**
A complete hydrological and hydraulic analysis is needed to assess the areas in the selected sub-basin(s) affected by flooding. This study will calculate the needed retention capacity and finally define the specific areas of the NbS application. An example of such a study is presented in Annex 4.

• **Second consultation with target audience**
After defining the areas of intervention, a second meeting with the target audience should be planned. Besides getting feedback on the selected areas, some first discussions in regards to the potential costs and benefits of associated trade-offs of the NbS intervention should be had.

• **Risk and impact assessment, proactive threat management**
Credible design processes require an assessment of the influence of social and ecological processes, and the risk of undesirable system change due to the occurrence of an external event (e.g. a natural hazard) and how this may influence the intended outcome of an intervention. The risk assessment should also consider the potential for increased vulnerability of some stakeholders as an unintended consequence of the intervention design.

• **Exploring the biodiversity benefits**
NbS interventions in the areas of concern should also aim to conserve or restore ecosystem integrity (i.e. biodiversity, structure & functions, and connectivity) and avoid further simplifying the ecosystem. Conservation targets should have already been discussed at a previous stage, while under this step, specific actions are foreseen:
- Planning and implementing adequate biodiversity surveys for data collection;
- Establishing contacts and synergies with the scientific community; and
- Drafting a biodiversity baseline study. This study will also set the basis for a preliminary risk and impact assessment and a monitoring and evaluation plan.

• **Exploring the economic viability**
A key challenge for the success of the NbS interventions in the selected areas is incorporating their multiple benefits into a common economic evaluation framework. Three actions are foreseen within this step:
- Mapping costs and benefits: the direct and indirect benefits and costs associated with the proposed NbS interventions will be identified and documented;
- Carrying out a cost-effective study to support the choice of NbS, including the likely impact of any relevant regulations and subsidies. The effectiveness of the NbS design must be justified against available alternative solutions, taking into account any associated externalities; and
- Considering a long-term business/financial plan to address the economic/financial feasibility and constraints of the NbS. This plan would look beyond the timeframe of the planning and initial grant-supported implementation phase.

• **Mainstreaming NbS**
All the process of design and relevant actions must circulate freely and openly and should be available and accessible to all audiences. A mapping of the gaps in current policies and regulations and a mapping of the global targets relevant to the project should be carried out. Three actions are foreseen:
- Preparing a detailed communication plan for the feasibility and design phase. The plan should include tools such as newsletters on lessons learnt, press releases on partnerships formed, capacity trainings on design or implementation, policy briefs and lobbying;
- Mapping existing policies, plans, laws and regulations, and highlighting gaps in the legal framework; and
- Mapping global targets relevant to the project. This will also include a mapping of the relevant national stakeholders who are responsible for these global targets.
5.4. Concept Design phase

The proposed objectives of the design phase are to deliver a well-structured programme with clear associated governance and financing arrangements (i.e., a business model) for the NbS programme’s success. In addition to the typical tasks covered in the concept design phase, this phase should involve transforming stakeholder interest into specific resource commitments (either direct or in-kind) to ensure that the regional investment plan has firm financial footing.

- Preparing the funding scheme for the implementation of NbS
  After completing the feasibility phase and reaching a consensus on the NbS interventions planned, the funding of the project should be defined. For this, extended meetings with relevant stakeholders (at a national and regional level) should be organised in order to decide on the most appropriate funding scheme and tool. Complementary actions (e.g. contracts, etc.) should also be foreseen.

- Designing a governance arrangement for NbS
  A proper governance structure shall be sought to make sure a long-term NbS programme can be delivered and maintained. Clear responsibilities and roles of local stakeholders should be defined.

- Third consultation with target audience
  As a part of the inclusive, transparent and empowering governance processes, meetings with the target audience should be organised again in the design phase. The local audience should be made aware of the feasibility phase results and informed on the specific steps of the concept design phase.

- Actions and safeguards for trade-offs
  Trade-offs can be successfully managed if consequences are properly assessed, fully disclosed and agreed-upon by the most affected stakeholders. Fair and transparent negotiations, and compensation for any loss as a result of the NbS are significant characteristics of good trade-offs. The potential costs and benefits of associated trade-offs of the NbS interventions in the areas of concern will be explicitly acknowledged and inform safeguards and any appropriate corrective actions. Additional meetings with the target audience should also been foreseen at this stage.

- Meeting with relevant authorities
  Meetings with relevant stakeholders (ministries, regional authorities and municipalities) should be planned to start preparing a more specific NbS strategy and an operational plan.

- NbS strategy/Monitoring & Evaluation framework /NbS Operational plan
  A specific NbS strategy for the region should be drafted at this step (such as a regional NbS implementation programme). This strategy should include a strong vision, a theory of change and an operational plan, based on the findings of the previous steps and actions. A monitoring and evaluation plan should also be included.

5.5. Execution phase

The proposed objectives of the execution phase are to clearly establish the implementation entity of the project and outline its operational structure, as well as to mobilise implementation capacity to deliver the NbS portfolio. This phase includes all elements of the project execution including procurement, detailed design, finance, construction, operation, monitoring and maintenance.

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75 For example, engaging technical experts to define the basic characteristics of the project to meet the main functional objectives; performing early calculations, sizings and in some cases early studies to confirm unknowns like geotechnical characteristics.
### 5.6. Indicative order of actions

**Table 5-1. Indicative actions in each phase and an indicative time order**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Actions</th>
<th>IUCN criteria/ indicator assessed</th>
<th>Indicative order of actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE FEASIBILITY</td>
<td>Nature for Catchments Launchramp (NCL) methodology</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Situation analysis</td>
<td>C.1-1, C.1-2, C.2-1, C.2-2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Consultation with local authorities</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Capacity building workshop</td>
<td>C.1-1, C.1-2, C.2-1, C.2-2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre-feasibility report</td>
<td>C.2-1</td>
<td></td>
</tr>
<tr>
<td>PREPARATION</td>
<td>Consultation with local authorities</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Meeting with competent ministries</td>
<td>C.2-2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Funding process defined and executed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>C.2-2</td>
<td></td>
</tr>
<tr>
<td>FEASIBILITY</td>
<td>Stakeholder mapping</td>
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</tr>
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<td></td>
<td>Grievance or dispute settlement mechanism</td>
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</tr>
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<td>1st Consultation with target audience</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Meeting with relevant authorities</td>
<td>C.1-3, C.2-1, C.2-2, C.3-2, C.4-1</td>
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<tr>
<td></td>
<td>Meeting with stakeholders working in finance &amp; insurance</td>
<td>C.2-1, C.2-2, C.4-1</td>
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<tr>
<td></td>
<td>Establishment of a steering committee</td>
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<td></td>
<td>Hydraulic and Hydrological study</td>
<td>C.1-3</td>
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<td></td>
<td>2nd Consultation with target audience</td>
<td>C.2.3, C.3-2, C.4-1, C.5-1, C.5-2, C.5-4, Intro to C.6-1</td>
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</tr>
<tr>
<td></td>
<td>Risk and impact assessment, proactive threat management</td>
<td>C.2.3</td>
<td></td>
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<tr>
<td></td>
<td>Biodiversity survey &amp; data collection</td>
<td>C.3-1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Meeting with scientific community</td>
<td>C.3-2, C.3-4</td>
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<tr>
<td>Concept Design</td>
<td>Execution</td>
<td></td>
<td></td>
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<tr>
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<td></td>
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<tr>
<td><strong>CONCEPT DESIGN</strong></td>
<td><strong>EXECUTION</strong></td>
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<tr>
<td>Biodiversity baseline study, Risk and impact assessment</td>
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<td>Mapping of costs and benefits</td>
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<td>Cost-effectiveness study</td>
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<td>Long term financial plan</td>
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<td>Prepare a detailed communication plan</td>
<td>C.8-1</td>
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<tr>
<td>Map of existing policies, plans, laws and regulations</td>
<td>C.8-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mapping of global targets and relevant stakeholders responsible</td>
<td>C.8-3</td>
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<tr>
<td>Prepare the funding scheme for implementation of NbS</td>
<td></td>
<td></td>
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<td>Design of governance arrangement for NbS</td>
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<tr>
<td>3rd Consultation with target audience</td>
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<td>Actions and safeguards for trade-offs</td>
<td>C.6-1, C.6-2, C.6-3</td>
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</tr>
<tr>
<td>Meeting with relevant authorities</td>
<td>C.7-1, C.7-2</td>
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<tr>
<td>NbS strategy/Theory of change</td>
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<tr>
<td>Technical concept design</td>
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</tr>
<tr>
<td>To be defined at a later stage</td>
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</table>
CONCLUSIONS
6. CONCLUSIONS

The present study has conducted a preliminary assessment of the feasibility of Nature-based Solutions (NbS) in the western part of Pineios River basin in Greece (western Thessaly) and of their ability to deliver critical services (benefits) including flood risk reduction and improvement of water availability (i.e. surface water and ground water). Other services, such as the creation of recreation opportunities (e.g. tourism) and the enhancement of biodiversity in the region were also explored. In the medium and long-term, the study aims to initiate a pilot project including NbS components in the region of Thessaly. This pre-feasibility report is the first step towards this objective.

Extreme flood events represent one of the most destructive natural hazards in the Thessaly region, with potentially significant negative impacts on communities and the economy. Large parts of the Pineos river basin are characterised as areas of potentially significant flood risk. The plain of Thessaly constitutes the most productive Greek agricultural territory. Flood risk reduction interventions that have been implemented in the past seem to have contributed only to a limited extent to protecting valuable assets and communities. Conventional “grey” infrastructure alone is not able to cope with recurring river floods in the region, due to their severity.

Nature-based Solutions (NbS) – an innovative concept focused on natural systems – seems to be a viable solution for fostering regional flood resilience and sustainability. NbS are primarily composed of flora, fauna, natural materials (e.g. rocks, soil and sand) and water, providing infrastructure-like services. Based on their capacity, they could complement, augment or even replace conventionally-built infrastructure.

There is a clear regulatory framework in several areas, including water management, flood protection, agriculture, and conservation policy issues in the region of Thessaly; however, the institutional framework is complex, with some overlaps between functions that may cause challenges when implementing and managing any NbS projects. There is very strong political will (at all levels) to reduce flood risk, as evidenced by the series of interviews with local municipalities and the capacity-building workshop conducted in Trikala in November 2021. However, the current plans focus heavily on grey solutions (including the potential creation of several new dams and other grey constructions in the target water catchment).

Through the stakeholder engagement with ministries, cities, and academic and financial institutions, this study confirms that proceeding with other technical studies (e.g. feasibility study) would be possible, both from a technical and a political standpoint. The study has identified the portfolio of NbS interventions tackling water security challenges likely to deliver the needed services in the context of the local challenges in the Thessaly region. In addition to that, the study has also identified potentially suitable locations in the Thessaly River basin where these interventions could maximise their services, if implemented. The outcomes of the study will need to be verified in other technical studies (e.g. feasibility study).

The cost of different NbS measures will depend on many variables, such as the cost of work and materials locally, the size of the proposed NbS interventions and their specific location, maintenance and operation costs. Cost estimates are typically done in later stages (e.g. Feasibility, Design), since more data is required for the cost analysis. At this stage, there is little data on the cost of different NbS types for Greece, due to a lack of NbS interventions already implemented on the ground. However, the project team has identified the real costs for two semi-natural water retention ponds that have been recently constructed in the Spercheios river catchment in Greece (refer to section: The Broader Context: Financing Nature-based Solutions). However, the costs for other NbS types (such as wetlands,
forests, or riparian buffers) can vary significantly. Further studies and analysis will need to be conducted in order to establish these cost estimations.

The project team has the expertise to address all the above considerations to catalyse bankable pilot projects in the Thessaly region. The feasibility study will be carried out in collaboration with key Greek experts, including representatives of academia, the financial sector, landscaping and engineering companies and regional institutions in charge of flood prevention. After the pre-feasibility stage, the project team has developed an in-depth understanding of the particular challenges faced by this region, and developed a wide network of local contacts that would prove invaluable to the implementation of the proposed NbS.
BIBLIOGRAPHY

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Galanis, Aristotelis (1933). The study of Boot Company on the hydraulic works in the plain of Thessaly, Boeotian Kifissos and Arta-Louros. τεχνικά χρονικά. Technical chronicles, official body of the...


Sigma 1/2022 - Natural catastrophes in 2021. Focus flood: building resilience against a rapidly growing risk.


Annex 1

Water-related challenges

River Floods
Floods in Greece are a common phenomenon, which has been increased over the last few decades leading to a significant number of human losses and important damages to infrastructures, communities and sectors. Specifically, the neighboring departments of Karditsa and Trikala in central Greece suffer from extreme rainfall events with high intensities and have historically been affected by severe floods. Annex Table 0-1 presents the significant historical flood events reported by the Flood Risk Management Plan for the River Basins of the River Basin District of Thessaly-EL08 (2018).

On September 18, 2020, an unprecedented catastrophic flood known as Medicane Iannos, considered one of the most disruptive events to hit the region, resulted in estimated economic losses totaling between EUR 0.5 – 1 billion. The accumulated rainfall exceeded 250 mm in less than 24 hours and resulted in widespread flooding, which caused damages in more than 5,000 households and shops in the city of Karditsa and also in 15 villages, while a total of 15 bridges collapsed.

Annex Table 0-1 Significant flood events in the Pineios river basin.

<table>
<thead>
<tr>
<th>A/A</th>
<th>DATE</th>
<th>IMPACT</th>
<th>X</th>
<th>Y</th>
<th>A/A</th>
<th>DATE</th>
<th>IMPACT</th>
<th>X</th>
<th>Y</th>
</tr>
</thead>
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<td>1</td>
<td>21-5-2016</td>
<td>Infrastructure and Rural Land Uses</td>
<td>358995</td>
<td>4347606</td>
<td>23</td>
<td>10-2-2018</td>
<td>Infrastructure</td>
<td>307569</td>
<td>4380493</td>
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<td>2</td>
<td>21-5-2016</td>
<td>Infrastructure and Rural Land Uses</td>
<td>369545</td>
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<td>Infrastructure</td>
<td>335397</td>
<td>4386984</td>
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<tr>
<td>3</td>
<td>21-5-2016</td>
<td>Infrastructure and Rural Land Uses</td>
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<td>4355951</td>
<td>25</td>
<td>10-2-2018</td>
<td>Infrastructure</td>
<td>326043</td>
<td>4385485</td>
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<tr>
<td>4</td>
<td>21-5-2016</td>
<td>Infrastructure and Rural Land Uses</td>
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<td>4356682</td>
<td>26</td>
<td>24-2-2018</td>
<td>Infrastructure</td>
<td>322815</td>
<td>4373532</td>
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<tr>
<td>5</td>
<td>21-5-2016</td>
<td>Infrastructure and Rural Land Uses</td>
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<td>24-2-2018</td>
<td>Infrastructure</td>
<td>335815</td>
<td>4402842</td>
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<td>6</td>
<td>21-5-2016</td>
<td>Infrastructure and Rural Land Uses</td>
<td>344012</td>
<td>4368313</td>
<td>28</td>
<td>24-2-2018</td>
<td>Infrastructure</td>
<td>327710</td>
<td>4404035</td>
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<tr>
<td>7</td>
<td>21-5-2016</td>
<td>Infrastructure and Rural Land Uses</td>
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<td>24-2-2018</td>
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<td>379351</td>
<td>4420063</td>
</tr>
</tbody>
</table>

76 The significant flood events presented herein cover the period 2016-2018. Annex Table 0-1 presents the date of the flood, what was impacted from the flood and the coordinates of the flood event. Coordinates are in GGRS 87, which is the projected coordinate system for Greece. It is observed that the main impact of flooding is on infrastructure (e.g. bridges, etc.) and on rural land uses (e.g. crops, livestock, etc.).
### Historical data on flood events

- In 1933, the estimated area of the Karditsa plain permanent marshes was 65 km², while the flooded agricultural land covered an area of 535 km² (Galanis, 1933).
- In Boot’s study (Galanis, 1933), a series of flood protection works (construction of embankments, mountain water collectors, lowland water collectors) and redirections of important rivers (Pliouris, Kalentzis, Farsalitis, Sofaditis, Enipeas, Lithaios, Neochoritis) were planned and implemented in their entirety.
- During the late 1960s/early 1970s, extensive works were carried out in Thessaly, aiming at the redistribution of land (land reform). According to Halstead (2019) and Krahtopoulou et al. (2020) “the redistribution of land was followed by comprehensive landscape reshaping works: wetlands were drained, riverbeds were redesigned and managed, and smaller streams receded and disappeared. At the same time, irrigation canals were constructed, roads and streams were redesigned to accommodate the new architecture of the area, and where the land presented hills, steep slopes and steep relief, extensive and sweeping earthworks were carried out, destroying forever, among other...
things, archaeological sites such as the "Magoules". Only one wetland was spared, named 'To Mati' (the eye), near the village Agioi Theodoroi, as it was thought to have magical and healing properties.

- According to a 1943 German map, wetlands and flooded areas in Western Thessaly covered an area of 76 km². Of these, 37 km² were located in the region of Karditsa, 23 km² in the region of Trikala and the remaining 16 km² were outside the administrative boundaries of Western Thessaly, but within the catchment area of Pineios river.

- Similarly, according to topographic maps of the British War Office & U.S. Army Map Service, wetlands and flooded areas in Western Thessaly in 1944 extended to 122 km² with most of them located in the region of Karditsa (49 km²), and fewer in the region of Trikala (29 km²).

Finally, extended flooded areas were located outside the administrative boundaries of Western Thessaly (44 km²), with the largest area being Lake Xiniada (36 km²) on the Ombriaki Plateau.

- The flooded areas from 1943 are very similar to those derived from the 1944 map (Annex Figure 0-1), which leads us to believe that the results obtained are close to reality. The discrepancies between the results from the 1943 and 1944 maps and Boot’s study may be due either to the fact that some drainage/reclamation works had already been carried out in the period 1933-1943/1944, or to the lower accuracy of the maps compared to the more focused Boot study.

- The Ianos Medicane, in September 2020, resulted in extended floods in Western Thessaly, mainly in the area of Karditsa. Flooded areas significantly coincided with the historical (1943 and 1944) flooded areas (Annex Figure 0-2). Other flood events (e.g. 1994, 2018) follow a similar pattern.
Annex 2

Regulatory framework

EU Water Framework Directive (WFD) and Greece

The first RBMPs of the country’s 14 River Basin Districts (RBDs) were finalised between April 2013 and September 2015, while the second RBMPs were adopted in 2017. Greece is currently at the end of its second round of River Basin Management Plans, which went from 2016 to 2021. The RBMPs outline the measures required to protect the water environment and safeguard the efficient and sustainable use of water. Most of the measures are related to agriculture and irrigation. The Thessaly basin is the pilot basin for Greece for the WFD.

The RBMP for Thessaly (GR08) was adopted in 2014, and the second RBMP was adopted on 21 December 2017. The public consultation for the third RBMPs (2022-2027) will start soon. The Thessaly basin has 86 water bodies and, according to the Report on the implementation of the Water Framework Directive River Basin Management Plans GR08, has the highest percentage of water bodies in poor and bad status (40%).

Annex Table 0-2 Competent authorities of Thessalia River Basin District

<table>
<thead>
<tr>
<th>Thessalia River Basin District (GR08)</th>
<th>River Basin</th>
<th>Percentage of area in every Region</th>
<th>Competent Decentralised Authority</th>
<th>National Competent Authority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pineios (GR16)</td>
<td>Thessaly (89.97%), Western Macedonia (1.76%), Central Macedonia (1.04%), Sterea Ellada (7.19%), Epirus (0.04%)</td>
<td>Thessaly</td>
<td>Special Secretariat for Water / YPEKA</td>
<td></td>
</tr>
</tbody>
</table>

Annex Table 0-3 Ecological quality status for each surface water body and water district, reference period 2010–2020

<table>
<thead>
<tr>
<th>Code</th>
<th>Water Districts</th>
<th>Ecological status of River Bodies (Number)</th>
<th>Ecological status of Lake Bodies (Number)</th>
<th>Ecological status of Coastal Water Bodies (Number)</th>
<th>Ecological status of Transnational Water Bodies (Number)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GR01</td>
<td>West Peloanpes</td>
<td>M 70 G 22 F 4 D 10 E U 0</td>
<td>M 0 G 0 F 0 D 0 E U 1</td>
<td>M 0 G 0 F 0 D 0 E U 2</td>
<td>M 0 G 0 F 0 D 0 E U 1</td>
</tr>
<tr>
<td>GR02</td>
<td>North Peloanpes</td>
<td>M 88 G 22 F 1 D 0 E U 0</td>
<td>M 0 G 0 F 0 D 0 E U 3</td>
<td>M 0 G 0 F 0 D 0 E U 1</td>
<td>M 0 G 0 F 0 D 0 E U 2</td>
</tr>
<tr>
<td>GR03</td>
<td>East Peloanpes</td>
<td>M 87 G 14 F 2 D 0 E U 0</td>
<td>M 0 G 0 F 0 D 0 E U 1</td>
<td>M 0 G 0 F 0 D 0 E U 2</td>
<td>M 0 G 0 F 0 D 0 E U 1</td>
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<tr>
<td>GR04</td>
<td>West Central Greece</td>
<td>M 71 G 15 F 4 D 2 E U 0</td>
<td>M 0 G 0 F 0 D 0 E U 1</td>
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<tr>
<td>GR05</td>
<td>Aegaon</td>
<td>M 26 G 10 F 1 D 2 E U 0</td>
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<td>M 0 G 0 F 0 D 0 E U 2</td>
<td>M 0 G 0 F 0 D 0 E U 1</td>
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<tr>
<td>GR06</td>
<td>Anthi</td>
<td>M 2 G 5 F 2 D 0 E U 1</td>
<td>M 0 G 0 F 0 D 0 E U 2</td>
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<td>M 0 G 0 F 0 D 0 E U 2</td>
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<tr>
<td>GR07</td>
<td>East Central Greece</td>
<td>M 33 G 5 F 5 D 5 E U 0</td>
<td>M 0 G 0 F 0 D 0 E U 1</td>
<td>M 0 G 0 F 0 D 0 E U 2</td>
<td>M 0 G 0 F 0 D 0 E U 1</td>
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<td>GR08</td>
<td>Thessaly</td>
<td>M 80 G 10 F 2 D 4 E U 2</td>
<td>M 0 G 0 F 0 D 0 E U 1</td>
<td>M 0 G 0 F 0 D 0 E U 2</td>
<td>M 0 G 0 F 0 D 0 E U 1</td>
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<td>GR09</td>
<td>West Macedonia</td>
<td>M 99 G 45 F 6 D 0 E U 0</td>
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<td>GR10</td>
<td>Central Macedonia</td>
<td>M 50 G 45 F 5 D 0 E U 0</td>
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<td>M 0 G 0 F 0 D 0 E U 2</td>
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<tr>
<td>GR11</td>
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<td>M 45 G 17 F 5 D 0 E U 0</td>
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<tr>
<td>GR12</td>
<td>Thessac</td>
<td>M 127 G 17 F 6 D 0 E U 0</td>
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<td>M 0 G 0 F 0 D 0 E U 2</td>
<td>M 0 G 0 F 0 D 0 E U 1</td>
</tr>
<tr>
<td>GR13</td>
<td>Grec</td>
<td>M 5 G 22 F 5 D 0 E U 3</td>
<td>M 0 G 0 F 0 D 0 E U 1</td>
<td>M 0 G 0 F 0 D 0 E U 2</td>
<td>M 0 G 0 F 0 D 0 E U 1</td>
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<tr>
<td>GR14</td>
<td>Aegean Islands</td>
<td>M 70 G 22 F 1 D 0 E U 0</td>
<td>M 0 G 0 F 0 D 0 E U 1</td>
<td>M 0 G 0 F 0 D 0 E U 2</td>
<td>M 0 G 0 F 0 D 0 E U 1</td>
</tr>
</tbody>
</table>

M = High; G = Good; M = Moderate; F = Poor; U = Unknown.

79 Source: Kourgialas, 2021.
As presented earlier, the Thessaly River Basin District is one of the areas identified as subject to floods (50-year return period; Annex Figure 0-3) at the national scale and are affected by their impacts from time to time. A recent example was the heavy rainfalls in Central Greece (September 2020), which flooded large parts of the Thessaly water district and caused significant damage in infrastructures and agricultural land (BBC, 2020, as cited in Kourgialas, 2021).

In relation to the inclusion in the Flood Risk Management Plan in terms of any NbS interventions, these are mentioned in relation to Natural Water Retention Measures. There are already existing anti-flooding works (focused on gray infrastructure such as dams, clearing of rivers, etc.), but according to the OECD (2020), the European Commission pointed out that NbS as a cost-effective flood protection could be more systematically explored.

Europen Directives and Greece


Source: Kourgialas, 2021.
Agricultural policy
According to the EU commission (2021), “to be supported by eco-schemes, agricultural practices should:

● cover activities related to climate, environment, animal welfare and antimicrobial resistance;
● be defined on the basis of the needs and priorities identified at national/regional levels in their CAP strategic plans;
● their level of ambition has to go beyond the requirements and obligations set by conditionality; and
● contribute to reaching the EU Green Deal targets”.

Climate Change Policy
According to the latest environmental report, the National Adaptation Strategy (NAS) “provides guidance, insight and priorities, which should be further detailed at regional level and translated into Regional Adaptation Action Plans. The law also foresees the establishment of a National Climate Change Adaptation Committee to act as the formal coordination and advisory body of the Ministry of Environment and Energy at National level for adaptation policy design, coordination and implementation. Work is ongoing to develop Regional Adaptation Action Plans. Each Regional Adaptation Action Plan will examine the potential measures and actions included in the National Adaptation Strategy, based on the particular regional characteristics, priorities and needs and will develop the regional priorities. Wherever there is a case for sector or sub-regional analysis, specific actions per sector or sub-regional area will be indicated. To date, there is no monitoring of the integration of climate change in sectoral policies, nor is there a framework that assesses adaptation actions that are being implemented. Greece will launch such a system in 2019 making use of EU funding programmes (LIFE integrated Projects)” (pp. 8-9).

Protected areas policy
According to the report by Mahleras et al. (2007), there are “twelve protected areas in the Pineios basin according to the definitions of Article 6 and Appendix IV of the Water Framework Directive 2000/60/EC. These are: two SPA (Special Protected Areas) and ten SCI (Areas designated for the protection of habitats or species where the maintenance or improvement of the status of water is an important factor in their protection). In terms of environmental flow requirements, according to the

Flood risk maps display, where necessary, flooding from the sea or flooding from groundwater, the surface inundated by the water, the maximum water depth, the maximum flow rate, and information on arrival times and stay duration of the flood wave landmarks within the areas flooded.

They describe the possible negative consequences associated with low/medium/high probability of exceeding flood and are formed based on the following parameters:

- Indicative number of inhabitants potentially affected;
- Types of economic activity of the area potentially affected;
- Facilities likely to cause pollution of the surrounding area in case of flooding;
- Protected areas, defined in Annex V (par. A 1,3 5) of Article 19 of P.D. 51/2007 liable to be affected; and
- Other information considered useful, such as the indication of areas where floods with a high content of transported sediments and floods that may cause mud flows or landslides, and information on other significant sources of pollution.

Source: OECD (2020)
Greek submission of WFD Article 5 Report to the EU, the estimation of the rivers’ minimum ecological flow can be made using different methods found in literature, practices followed in other countries, as well as suggestions made in older research projects in Greece (for example, the land planning program of Greece by Doxiadis).”

Organisations responsible for the various flood risk reduction related activities

<table>
<thead>
<tr>
<th>Measures proposed as part of Flood Risk Management Plan (FRMP) / specific activities</th>
<th>Implementer of measure / responsible for activities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flood anticipation</strong></td>
<td></td>
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<tr>
<td>(FRMP) Use of existing water storage projects to reduce flood flows</td>
<td>Dams management bodies</td>
</tr>
<tr>
<td>(FRMP) Maintenance of existing Mountain hydrological works</td>
<td>Decentralised Administration of Central Greece/Forests Directorate and forests departments</td>
</tr>
<tr>
<td>(FRMP) Land use management measures in torrent basins</td>
<td>Ministry of Infrastructure and Transport, Ministry of Environment, Decentralised Administration of Central Greece</td>
</tr>
<tr>
<td>Study, implementation and maintenance of flood protection works</td>
<td>Ministry of Environment, Ministry of Rural Development and Foods, Decentralised Administration, Municipalities, Land improvement agencies</td>
</tr>
<tr>
<td>Evaluation and Management of Flood risks</td>
<td>Ministry of Environment, Special Secretariat for Water, Water Directorate in Region Authorities and Decentralised Administrations, General Secretariat for Civil Protection of Greece</td>
</tr>
<tr>
<td>Forecasting of dangerous weather phenomena, increased preparedness to deal with risks from flood events</td>
<td>National Meteorological Service, Civil Protection Operations Centre/National Coordination Centre for Operations</td>
</tr>
<tr>
<td><strong>Flood prevention</strong></td>
<td></td>
</tr>
<tr>
<td>(FRMP) Modernisation and rehabilitation of sewerage/drainage networks</td>
<td>Many</td>
</tr>
<tr>
<td>(FRMP) Projects to replace and supplement existing rainwater drainage networks</td>
<td>Region of Thessaly, Ministry of Infrastructure and Transport/General Secretariat of Infrastructure/Directorate-General for Hydraulic and Building Infrastructure/Flood and Land Reclamation Directorate, Municipalities,</td>
</tr>
<tr>
<td>Forestry works for winter forestry, flood and erosion control in forests and woodlands</td>
<td>Ministry of Environment/General Directorate for Development and Protection of Forests and Rural Environment/Directorate of Forestry Works and Infrastructure, Forestry Services/Decentralised Administration</td>
</tr>
<tr>
<td>Informing the public on how to take self-protection measures against the risk of flooding</td>
<td>General Secretariat of Civil Protection, Civil Protection Directorate/Decentralised Administration, Civil Protection Directorates/Regional Authority, Civil Protection Departments/Regional Units, Civil Protection Offices/Municipalities, NGOs, Agricultural Economy Directorates/Regional Authority, Agricultural Economy and Veterinary Directorates/Regional Unit</td>
</tr>
<tr>
<td>Flood preparation</td>
<td>(FRMP) Promotion of flood flow and sediment retention practices with emphasis on Natural Water Retention Measures</td>
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<tr>
<td>-------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
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<tr>
<td></td>
<td>(FRMP) Flood protection studies/projects</td>
</tr>
<tr>
<td></td>
<td>(FRMP) Preparation of master plans for flood protection projects</td>
</tr>
<tr>
<td></td>
<td>Responsibilities for the design, commissioning and execution of settlement, flood protection and maintenance works</td>
</tr>
<tr>
<td></td>
<td>Cleaning and policing of streams</td>
</tr>
</tbody>
</table>

**Responsibilities of key actors in flood risk management**

**Policy design**

At the national scale, more specifically, in terms of policy planning, the General Secretariat for Civil Protection of Greece prepares, mobilises and coordinates the country's civil protection capacity but also studies, plans, organises and coordinates means of action for the prevention and response to natural, technological and other disasters or emergency situations, as well as the information of the public on these issues. It coordinates disaster response work and actions during the occurrence of the events, as well as the work of restoring the damage caused. Additionally, it makes use of available scientific data and information to mobilise the country's civil protection capacity and assets in the face of an imminent disaster risk.

In terms of centralised authority which is decentralised to the regions, the **Decentralised Administration of Thessaly and Central Greece, Directorate of Civil Protection** is responsible for planning and organising the prevention, information and response to disasters or emergencies, as well as for the coordination of all services of the Decentralised Administration to ensure preparedness, disaster response and damage restoration. Similarly, the **Ministry of Infrastructure and Transport, General Secretariat of Infrastructure, Directorate General for Natural Disaster Recovery** plans for the response and restoration of the effects of natural disasters on the country's structural wealth.
At the regional scale, the Region of Thessaly, Directorate of Technical Works deals with the planning, programming, and coordination of technical works throughout the Region, as well as the design, execution, supervision, acceptance and maintenance of technical works.

Policy implementation
In terms of policy implementation, the Ministry of Environment, Special Secretariat for Water is responsible for the implementation of the Water Framework directive (2000/60/EC) and the Floods Directive (2007/60/EC), with the cooperation of the Water Directorates of the Decentralised Administrations of Greece. The Western Thessaly falls under the Thessaly basin 08, which is managed by the General Secretariat for Natural Environment & Water General Directorate of Water.

Additionally, the Natural Environment and Climate Change Agency (NECCA) implements the policy of the Ministry of Environment and Energy for (i) the management of protected areas in Greece, the conservation of biodiversity and (ii) the promotion and implementation of sustainable development and climate change actions.

The Directorate of Environment and Spatial Planning of Thessaly is in charge of the planning and implementation of environmental, spatial and urban planning policy in the Region of Thessaly, in the context of the principles and national guidelines for environmental protection and sustainable development, depending from the Ministry. However, it is the Directorate in the region that is responsible for its actual implementation (see below).

Investment
From an investment point of view, the Bank of Greece, Climate Change Impacts Study Committee (CCISC) is engaged in the study of the economic, social and environmental impacts of climate change, implementing research projects in a wide range of areas, including the economics of climate change, and disseminating research results through various events and activities.

Operational Management
The evaluation and management of flood risks is dealt with, for regional level matters, by the Water Council of the Decentralised Administration, Decentralised Administration of Central Greece, Water Directorate of Thessaly, while at the national level this is the responsibility of the National Water Committee, National Water Council, Special Secretariat for Water.

Regulation and enforcement
In terms of regulation and enforcement, the responsible entity for monitoring and evaluation of the progress of the action plan of the Flood risk management plan is the Special Secretariat for Water (Ministry of Environment) at a national scale and the Water Directorate of Thessaly (Decentralised Administration of Central Greece) at a regional scale. Additionally, the Decentralised Administration of Central Greece, Water Directorate of Thessaly is responsible in particular for the protection and management of water in the Region of Thessaly and exercises the powers assigned to the Decentralised Administration in accordance with the legislation in force, while the Decentralised Administration of Central Greece, Forests Directorate is responsible for duties such as forest development, protection and mapping as well as property issues in the county. The Head of the Forestry Department also has coordinating duties for the proper functioning of the

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82 https://necca.gov.gr/
Forestry Department in his/her area of responsibility. He/she provides instructions and guidance to the Forestry Offices on any matter arising in the exercise of their responsibilities, coordinates their operation and submits a quarterly report to the Head of the Directorate General of Forests and Rural Affairs on the operation of each Forestry Office separately.

The responsibilities of the **Directorate of Environment and Spatial Planning** include the control of compliance with environmental conditions for activities and projects in accordance with the applicable legislation, the adoption of measures for the protection of the environment, the preparation and approval of the regional solid waste management plan within the framework of the corresponding national plan in accordance with the applicable legislation and the implementation of measures, programmes and actions of the region, as well as the study and development of the spatial planning and development of the regional waste management system. Some of these duties are also dealt with by the Department of Environment.

Finally, the **Decentralised Administration of Central Greece, Directorate of Rural Affairs of Thessaly** is responsible in particular for issues of reforestation and settlement, as well as issues of farms and fisheries in the region of Thessaly, in accordance with the legislation in force.

However, we have no information about who is responsible for:
- Policy implementation: Financing & budgeting, Stakeholder engagement, Evaluation
- Investment: Financial resource mobilisation
- Operational management: Infrastructure operation
- Regulation and enforcement: Tariff setting, Developing standards, Issuing and acquiring licensing

**Extract from OECD Report on Flood Insurance**

"Market penetration for flood insurance coverage is very low, compared with other OECD countries (OECD, 2016b). Over the last decade Greece has claimed damages to the EU Solidarity Fund for one major and three regional floods, which caused damages of over EUR 3 billion. The total EU aid granted for flood recovery amounts to EUR 112.7 million (European Commission, 2017)."

Annex Table 0-5 Protection against coastal and river flood risks: projected growth rates of investment needs to 2030.

<table>
<thead>
<tr>
<th>GREECE</th>
<th>Expenditure to protect against river flood risk</th>
<th>Expenditure to protect against coastal flood risk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total growth factors by 2030</td>
<td>Categories (1-4) by 2030</td>
</tr>
<tr>
<td></td>
<td>Expected urban damage</td>
<td>Expected affected population</td>
</tr>
<tr>
<td></td>
<td>1.61</td>
<td>0.68</td>
</tr>
</tbody>
</table>

Source: OECD, 2018
Annex 3

Description of Pineios sub-basins

Sub-basin: Enipeas (K1)

Area of sub-basin: 1140.5 km²

Main rivers: Enipeas

Main cities affected by river flooding: Yperia, Orfana, Fyllo, Astritsa, Ampelonas, Ilias

Objective: Mitigate the flood risk for the settlements in the lower part of the Enipeas river

Description: The Enipeas river flows from the Omvriaki plateau, and its bigger part is located out of the administrative boundaries of western Thessaly, while only ~17 km run within the study area. In the area between villages Orfana & Fyllo, Enipeas has been diverted and nowadays the main course is heading towards the west to the old riverbed of the Ofios stream (which passes north of Ilias village and south of Petrino and Sykies).

This diversion happened after the 1940s, as aerial photos from the Greek Cadastre and the 1944 maps from the British War Office and U.S. Army Map Service show no interventions in the area before that time.

Based on the modelling results of the FRMP, strong flooding phenomena occur in all return periods. In the return period T=50 years, flooding exceeds the limits of the riverbed over a long length of the river section, spreading within the areas on both sides of the river and affecting a large proportion of the settlements: Yperia, Orfana, Fyllo, Astritsa, Ampelonas and Ilias. The situation is most unfavourable for T=100 and T=1000 years, as greater depths of flow occur and flooding covers bigger areas, affecting other villages and rural space. In most cases, these floods coincide with historical flood plains (Annex 2). According to the FRPM, flood events also occur upstream of the study area, affecting settlements like Lofos and Pyrgakia. However, as the study area is western Thessaly, the proposals will focus only on the lower course of Enipeas, although it would be more appropriate to study the whole Enipeas system.

The new course of Enipeas (old Ofios stream) has embankments only in the south riverbed, to protect villages such as Ilias, Itea, and others, from getting flooded. Moreover, the old riverbed of Enipeas still exists, although its width is very narrow. Ideally, the widening of the two riverbeds and the connection with floodplains should be explored, although this might be challenging.
**Sub-basin:** Sofaditis (K3)

**Area of sub-basin:** 648,1 km²

**Main rivers:** Sofaditis & Rogozinos

**Main cities effected by river flooding:** Sofades, Markos, Kalyvakia, Pyrgos Kieriou and Moscholouri

**Objective:** Reduce the flood risk for Sofades and the villages in the lower part of Sofaditis basin

**Description:** Sofaditis, the main river of the area, comes mainly from Omvriaki plateau and a mountainous area close to Rentina village. It crosses the plain of Thessaly toward the north where it meets Enipeas river close to Vlohos village. In 2002, the artificial dam lake of Smokovo, having a capacity of 237 x 10⁶ m³ was constructed in the riverbed of Sofaditis, extending in an area of 8.5 km². During the period 1936-1942, lake Xiniada, located in the Omvriaki plateau (with a surface of 31.6 km² and maximum depth of 4m), was drained and transformed into agricultural land. However, as the productivity of farmland has been significantly reduced due to soil degradation, arguments for the restoration of the lake have recently emerged. A second smaller river, Rogozinos, drains the waters from a smaller basin to the east of Sofades and flows through the Thessalian plain parallel to Sofaditis where they meet a few hundred meters south from Markos village. In the past, the river was heading north, passing next to Markos village, where it met Kalentzis very close to Metamorphosi village. After the land reform of the 1960s-1970s, the course of the river was changed to its current position. According to the FRMP, intense flood phenomena occur in all return periods, for specific sections of the two rivers: from Sofades to the junction of Sofaditis with Farsaliotis and from Ampelos village to the junction of Rogozinos with Sofaditis. For return period T=50 years, flooding exceeds the riverbed boundaries along these two sections of the rivers, spreads along the agricultural land and largely affects Sofades and the surrounding area. The situation is more unfavourable for T=100 and T=1000 years, as greater flow depths occur and floods take up more space, affecting the villages of Sofades, Markos, Kalyvakia, Pyrgos Kieriou and Moscholouri. Flooding is more intense in the area close to where Sofaditis meets Enipeas, where a larger area is affected. For the purpose of our calculations, Smokovo Lake is considered to be at its maximum operating level at the beginning of the rainfall and as a result it’s not contributing to flood mitigation. In reality, as many flooding events occur in autumn, the lake’s water level is not at its maximum, meaning that the lake’s contribution is significant.
Sub-basin: Kalentzis (K4)

Area of sub-basin: 653.8 km²

Main rivers: Kalentzis, Karambalis, Gavras and Lipsimos

Main cities affected by river flooding: Karditsa, Myrina, Makrychori, Koskinas, Metamorphosi, Psathohori, Artesiano, Paragogiko and Agii Apostoli, Paleoklisi

Objective: Reduce flooding in Karditsa city and the villages in the lower course of Kalentzis

Description: The total length of the entire hydrographic network is 104 km and it is located within the administrative boundaries of western Thessaly and the catchment area of Pineios River. According to the FRMP, intense flood phenomena occur in all return periods, mainly for the areas that include the sections of Gavras River, the upper and the lower course of Kalentzis river. For return period T=50 years, flooding exceeds the riverbed boundaries along a large part of the river section, spreads within the areas on both sides of the river and severely affects the settlements of Myrina, Makrychori, Koskinas, Metamorphosi, Psathohori, Artesiano, Paragogiko and Agii Apostoli. The situation is more unfavourable for T=100 and T=1000 years, as greater flow depths occur and floods take up more space, also affecting the village of Paleoklisi and larger rural areas. These findings also coincide with the historical flood plains described in Annex 1.

Karditsa, although not mentioned in the FRMP as a priority area, has repeatedly suffered from floods. Among the most severe was the Ianos medicane (September 2020), which caused extensive damages both to infrastructures and properties, while half the city was covered by waters and mud. The increased flood risk in the area is associated with the three main rivers Gavras, Karampalis and Kalentzis. The Gavras River flows from the mountains west of the city, heading to Mitropoli village. From that point and until it meets Karambalis at the south of Karditsa, Gavras has been transformed into an artificial channel that can barely hold the waters in case of heavy rainfalls. The Karambalis River flows from the south, and largely retains its 1945-1960 riverbed. However, the Ianos medicane showed that the width of the riverbed could not hold large amounts of water; the river overflowed close to Rousso village and the embankments south of Karditsa were overpassed, letting the water enter the city. Finally, Kalentzis comes from Apidia village, heads north towards Karditsa and meets the other rivers to the west of the city. Kalentzis also receives the water from other minor streams that have been diverted in the past (e.g. Lipsimos in Karpochori village, and an anonymous stream coming from Agiopigi). Similarly, Kalentzis’ riverbed hasn’t been changed since 1945-1960. In the past, there were plans to create a flood plain within the triangle created by these three rivers to the west of Karditsa with the aim of mitigating floods; however, this has not been implemented.

During the interviews with the Mayor of Karditsa and the workshop in Trikala, it was mentioned that there are plans for the construction of two dam lakes, one in Kalentzis river, close to Dafnospilia and one in Karambalis to the south of the village of Kallithiro. The purpose of these dams is primarily for irrigation, although they might also contribute to flood mitigation.
**Sub-basin:** Pamisos (K6)

**Area of sub-basin:** 247.7 km²

**Main rivers:** Pamisos

**Main cities effected by river flooding:** Palaiochori, Agnantero, Kalogriana, Agia Triada, Proastio, Megala Kalyvia, Mouzaki.

**Objective:** Reduce the flood risk for Mouzaki, mitigate the flood risk for settlements in the lower part of Pamisos river (Megala Kalyvia, Agnantero, Palaiochori).

**Description:** Pamisos flows from a relatively small area of Agrafa Mountains, crosses Mouzaki and runs in the Thessaly plain to the east. In the past, the river passed close to Magoula village towards further east, running between Kalogriana and Rizovouni and reaching Mega River. However, at some point after 1945, it was diverted through a channel to Pineios River just between Megala Kalyvia and Agnantero. Based on satellite images and historical aerial photos, it seems that this channel cut the natural flow of the historical Pamisos riverbed and other smaller streams and probably now acts as a barrier, preventing the water from Megala Kalyvia from running free, thus creating a flooding problem close to the village. Adding to that, the flat ground with zero slopes in the extended area between the villages of Palaiochori, Agnantero, Kalogriana, Agia Triada, Proastio often contributes to creating floods after heavy rains and river overflow. As the FRMP indicates, the situation is most unfavourable for T=100 and T=1000 years, as greater depths of flow occur and the flood extend to larger areas.

As regards the city of Mouzaki, significant changes have been made to the Pamisos riverbed. A comparison of contemporary pictures to aerial photos from 1945-1960 (from the National Cadastre and Mapping Agency) show that the width of the Pamisos riverbed has been largely reduced and the river confined between embankments. Newly acquired land was covered by public buildings and other infrastructures (e.g. traffic education centre). Figure 4.5 (chapter 4.3.6) depicts the extent of human intervention: the yellow line indicates the 1945-1960 riverbed, while the blue line shows the contemporary boundaries of the river. In area A, where the medical centre of Mouzaki collapsed, the riverbed was reduced from 197 metres (green line) to 63 metres (red line). Respectively, in area B, the width was reduced from 357 metres to 107 metres, while in area C the width was halved (from 213 metres to 107 metres).
### Sub-basin: Lake Plastira (K7)

<table>
<thead>
<tr>
<th><strong>Area of sub-basin:</strong></th>
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<tbody>
<tr>
<td><strong>Main rivers:</strong></td>
<td>-</td>
</tr>
<tr>
<td><strong>Main cities affected by river flooding:</strong></td>
<td>-</td>
</tr>
</tbody>
</table>

**Objective:** Mapping and surveying the bottom of the lake to provide a better knowledge on the decrease of the lake’s effective volume.

**Description:** Although Lake Plastira is not included in the Pineios water basin, all its water is being transferred to the Thessaly plain for irrigation and water supply. However, since its creation in the late 1950s, sediments and debris have collected in the lake’s bottom and never been removed, thus causing a decrease of the effective volume of the lake. According to information acquired by the Mayor of Limni Plastira, the Ianos Medicane worsened the problem, as many landslides occurred in the area and a significant volume of sediments ended up in the lake.

The goal of the proposed action is to collect all the necessary scientific data and provide a better overview as regards the decrease of the lake’s effective volume. Although this is not an NbS intervention, the contingent sediment removal from the bottom of the lake will also reduce the need for grey infrastructure (dams) in the Thessaly plain to deal with the water scarcity challenge.
Sub-basin: Portaikos (T1)

Area of sub-basin: 301.7 km²

Main rivers: Portaikos, Bedenis, Boufotas, Anapodos, Aforesmeno, Paliopatamos

Main cities effected by river flooding: Ammoudia, Drosero, Parapotamos, Kato Elati, Mesiaka, Lili, Valtino, Matsoukiotika, Meligos, Dilofo, Fiki, Pyli, Eleftherochori

Objective: Reduce the flood risk for Pyli, mitigate the flood risk for settlements in the lower part of Portaikos sub-basin

Description: Portaikos, the main river of the area, flows from the western Agrafa mountains, crosses the city of Pyli towards the north east and meets the Pineios river right after Parapotamos village. Smaller rivers run to the north of Portaikos (Bedenis, Boufotas, Anapodos, Aforesmeno, Paliopatamos) and although their bed widths have not been reduced since the 1940s, FRMP modeling results show that the area around them is prone to flooding. The Portaikos riverbed has not significantly changed either; however, historical flood plains (as depicted in the 1944 maps from the British War Office and U.S. Army Map Service) have been transformed into agricultural land.

Based on the modelling results of the FRMP, flooding phenomena occur in all return periods. In the return period T=50 years, the flooding exceeds the limits of the riverbed in some parts of the rivers and the flood affects cultivated areas areas and some settlements in the lower part of the basin. The situation is most unfavourable for T=100 and T=1000 years, as greater depths of flow occur and the flood covers bigger areas, affecting larger cultivated areas and settlements such as Ammoudia, Drosero, Parapotamos, Kato Elati, Mesiaka, Lili, Valtino, Matsoukiotika, Meligos, Dilofo, Fiki, Eleftherochori and Pyli.

The proposed measures include the widening of specific sections of the rivers Bedenis (close to Fiki village), Anapodos (between the villages of Eleftherochori and Matsoukiotika), and the lower section of Portaikos, the restoration of past flood plains that have been transformed into agricultural areas, and the connection of specific sections of Portaikos and the Aforesmeno stream with adjacent public land to mitigate flooding in the area. In addition, in order to reduce the flood risk for Pyli, specific interventions are proposed aiming at restoring the riverbed of Portaikos close to the city.
**Sub-basin:** Lithaios-Agiamoniatis (T2)

**Area of sub-basin:**
395.5 km², of which ~302 km² is the Lithaios sub-basin

**Main rivers:** Lithaios and Agiamoniatis

**Main cities affected by river flooding:** Karyes, Trikala

**Objective:** Reduce the flood risk for Trikala and the areas downstream of Trikala

**Description:** The Lithaios river flows from the western foothills of Antichasia mountain, while Agiamoniatis is located northwest of Trikala, in the plain between the Lithaios and Pineios rivers, with a total river length of 23.4 km. According to the FRMP, intense flood phenomena occur in all return periods. For Agiamoniatis, even for return period T=50 years, the flood exceeds the riverbed along a large length of the river section and spreads into the areas on both sides of the river. The situation is more unfavourable for return periods T=100 and T=1000 years, as greater flow depths occur and floods take up more space, while Karyes village is affected for return period T=1000 years. Similarly, for Lithaios river, flood events occur during all return periods. For T=50 years, water exceeds the riverbed and flooding spreads within the urban area of Trikala, while for return periods T=100 and T=1000 years, the picture is more unfavourable.

Trikala, although not severely hit by the latest floods (2018, 2020, 2021), has suffered from catastrophic events during the last century. Among the most infamous was the 1907 overflow of Lithaios river, which resulted in major disasters and significant human losses.

The increased flood risk for Trikala derives mainly from the river basin of Lithaios (fluvial floods) but also from backwater effect, resulting from the overfeed of Pineios river. In the past, numerous interventions have been made aiming at reducing the flood risk: the delineation and dredging of Lithaios river within the city (completed in 1947), the diversion of Lithaios to Pineios from Theopetra to Peristera (completed in 1937), and the diversion of Lithaios within the city of Trikala that practically inactivated the old river course from Trikala to Klokotos village (works started in 1937).

The construction of a dam lake, 4.7 km northeast from village of Spathades has been planned and is in progress. Although the purpose of the dam is for irrigation, it is also expected to contribute to the reduction of fluvial floods coming from Lithaios. The reservoir will cover an area of 253,000 m², with a water volume of 2,500,000 m³.
**Sub-basin:** Ano Pineios (T4)

**Area of sub-basin:** 1130.2 km²

**Main rivers:** Pineios, Klinovitikos, Kastaniotis, Malakasiotikos, Ion (Mougkanis)

**Main cities effected by river flooding:** Megarhi, Dialehto, Dipotamos, Rogkia, Valtino, Matsoukiotika, Meligos, Fotada, Valamandri, Kato Elati, Mesiaka, Ammoudia, Parapotamos, Trikala, Flamouri, Agia Kyriaki, Sarakina (some of the settlements belong to other sub-basins)

**Objective:** Reduce the flood risk for settlements of the lower part of the sub-basin

**Description:** This sub-basin contains the upper part of the Pineios River along with its tributaries: Klinovitikos, Kastaniotis, Malakasiotikos, Mikanis, and other smaller rivers. As defined by the FRMP, the junction of Pineios with Portaikos sets the lower boundaries of the sub-basin. This sub-basin contains the upper part of Pineios along with its tributaries: Klinovitikos, Kastaniotis, Malakasiotikos, Ion and other smaller rivers. As defined by the FRMP, the junction of Pineios river with Portaikos sets the lower boundaries of the sub-basin. Extensive interventions in the upper section of the Pineios riverbed have reduce the width by – in some cases – hundreds of metres. For example, near the city of Kalambaka, the 1940 aerial photos from the Greek Cadastre reveal that the width of the river was approximately 1200 m, but it has since been reduced to ~400 m. Because of infrastructures developed in this area (e.g. national road E65), extensive interventions to restore the initial riverbed are almost not possible.

Based on the modelling results of the FRMP, strong flooding phenomena occur in all return periods, exclusively on the lower part of the sub-basin (starting 3 km north of Diava village up to the end of the sub-basin close to Parapotamos village). In the return period T=50 years, the flooding exceeds the limits of the riverbed over a long length of the river section, spreading within the areas on both sides of the river and affecting the villages of Sarakina, Dialehto, Fotada, Valamandri and Kato Elati. The situation is most unfavourable for T=100 and T=1000 years, as greater depths of flow occur and the flood covers bigger areas, affecting other villages (Peristera, Megarhi, Kefalovriso, Dipotamos, Rogkia) and rural space.
Examination of retention ponds
design volume and impact in
reducing the flood inundation area

1. Introduction

Floods are currently among the deadliest weather-related hazards worldwide. In the Mediterranean, flash floods have recently caused huge economic damages and claimed human lives (Bournas and Baltas, 2021; Diakakis et al., 2019; Feloni et al., 2020; Varlas et al., 2019). Flood prevention measures are therefore sought, in order to mitigate flood damages. In Europe, the implementation of the European Flood Directive 2007/60 has the goal to assess the vulnerability of each state against flooding, and provide the basis for complete management plans. These flood management plans include structural and non-structural measures to mitigate flood damages. Although current practice focuses on non-structural methods, such as early warning systems and advanced legislation initiatives concerning land use (Bournas and Baltas, 2020), structural measures are still deemed essential, especially in cases where flooding occurs often and is uncontrolled. Structural measures include dams, levees and retention ponds and are designed for specified rainfall characteristics. Under environmental and climate-change policies, the environmentally friendly aspect of the structures is highly sought after, and therefore multiple smaller-scale structures are preferable to single large installation, such as dams. Therefore, large dams are usually excluded from the design process, since they are hard to implement and sustain. Instead, small dams or retention ponds are preferred as a measure against flooding, since their smaller size does not alter the terrain significantly, while the ability to construct multiple ones not only provides the required protection downstream, but also contributes to reducing the maximum discharge in multiple places within the basin as well.

In order to design such structures, a complete hydrological and hydraulic analysis is needed, to assess the areas affected by flooding. Current studies couple hydrologic and two-dimensional (2D) numerical simulation models to perform the needed flood simulations (cf. Bournas et al., 2019; Rollason et al., 2018; Thakur et al., 2017), since incorporating a 2D scheme provides better results and proves to be an important tool for understanding flood events when high uncertainty is involved due to the scarcity of data (Bhandari et al., 2017; Quirogaa et al., 2016). In this work, the hydrological analysis was performed with the aid of the Hydrologic Modeling System (HEC-HMS), while the hydraulic analysis was performed with the use of the HEC River Analysis System (HEC-RAS). The desired volume which the retention ponds should be designed for was calculated by comparing the volume of the 50-year Flood Hydrograph (FH) against the FH that can be safely routed through the region.

2. Study Area and Data Used

The selected study area is the upper part of the Pineios river basin, located in Central Greece, within the Thessaly River Basin District (RBD), as shown in Annex Figure 0-4. The sub-basin is surrounded by the Pindos mountain range on the west, the Chasian mountains on the north, while on the west its outlet is located after the Mourgani settlement, just before the Kalambaka city. The outlet is located a few meters before the converge of the Pineios mainstream with two substreams, the Malakasitiko and Kleinovitikos substreams, therefore a large amount of discharge is expected downstream. The sub-basin total area is 949.64 km², and its mean elevation is 1102.65 m.
Annex Figure 0-4 Study Area, Upper Pineios Sub-basin

Annex Figure 0-5 Methodological Framework
The datasets used in the analysis are the following; a) a Digital Elevation Model (DEM) provided by the National Cadastre & Mapping Agency S.A., which features a 5 m x 5 m grid elevation dataset with a geometric accuracy RMSE of \( z \leq 2.0 \) m and an absolute accuracy about 3.9 m for a 95% confidence level, b) the “CORINE Land Cover” (2018) (CLC) dataset, which provides the land cover and land use patterns, and c) the Intensity Duration Curves (IDF) of nearby located stations, as derived in the course of the Flood Risk Management Plans for Greece by the Ministry of Environment, Energy and Climate Change (SSW-MEECC, 2017) and officially applied in Greece. There are five stations which affect the study area, as shown with red triangles in Annex Figure 0-4.

3. Methods

The main methodology followed in this research study, consists of a full hydrological and hydraulic analysis at the designated area as shown in Annex Figure 0-5. The designed rainfall height is derived through the use of the IDF curves for a return period of 50 years, a typical value for flood retention works for a rainfall duration of 24 hours, based on the basin size and time of concentration.

The rainfall timeseries is then constructed with the use of the alternating blocks method, where the maximum rainfall height is located in the middle of the rainfall duration. Since a lumped scheme is selected for the hydrological simulation, the mean rainfall of the sub-basin is calculated through the use of the Thiessen polygon method, where the weight of each station is calculated in accordance with the area of influence percentage each has in the total area of the sub-basin. These calculations, along with the derivation of the sub-basin characteristics, i.e. watershed bounds, area, river placement, mean Curve Number (CN) value etc., are performed in the Geographical Information Systems (GIS) environment, through the use of the ArcGIS spatial analyst toolbox.

The hydrological analysis is performed through the HEC-HMS platform. The rainfall-runoff transform method used, is the Snyder Unit Hydrograph (UH), while the rainfall losses are calculated through the Soil Conservation Service (SCS) CN method. The FH exported, with a time step of one hour, is then imported into the HEC-RAS model in order to produce the flood inundation maps. The CLC data are used in order to derive the manning roughness coefficient, n, values based on literature (Arcement and Schneider, 1989). The hydraulic simulations are performed for the derived FH, as well as for various scenarios where retention ponds upstream would limit the extend of the flood. In order to calculate the desired flood volume that will need to be held, first multiple hydraulic simulations are performed in order to derive the maximum discharge that can be safely routed through the study area. The FH of these runs are equal in size with the 50-year FH, but by imposing a limit in the maximum discharge value, as an effect of design measures. The difference between the two hydrographs volumes, i.e. the 50-year and the designed FH, is the needed design volume which the retention ponds should retain. The above are summarised in Annex Figure 0-6.

4. Results

Applying the aforementioned methodology, first the basin characteristics required for the application of the Snyder and CN loss methods are derived and presented in Annex Table 0-6. As seen by the value of the longest flow path and centroidal longest flow path, the basin shape is rather symmetrical, with the outlet stationed near the centroid of the basin, resulting in high discharge peak values, since large amounts of water converge at the outlet.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Study Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>949.64 km²</td>
</tr>
</tbody>
</table>
Through the use of the HEC-HMS platform, the 50-year FH is derived for the desired location, shown in Annex Figure 0-7. In the same Figure, two scenarios used as the effect of the retention ponds upstream are also shown, the $Q_{500}$ and $Q_{700}$, which are constructed by limiting the maximum discharge values allowed to $500\text{m}^3/\text{s}$ and $700\text{m}^3/\text{s}$ respectively.

Finally, in Annex Figure 0-8 to Annex Figure 0-10 the inundation maps of the three scenarios are shown, i.e. the 50-year ($T_{50}$), and the $Q_{500}$ and $Q_{700}$, scenarios. As seen in the inundation maps, the $T_{50}$ FH results in flood outside the river bed, therefore flood preventing measures in the studied region are deemed mandatory. By applying the $Q_{700}$ scenario, while flooding is limited, both in terms of area covered and maximum depth, there is still no safe routing of the flood. In the latter case (the $Q_{500}$ scenario), the generated flood volume is safely routed. By calculating the difference in the FH volumes between the default and the $Q_{500}$ scenario, as seen in Annex Table 0-7, it is found that approximately 17 million m$^3$ of runoff volume should be retained by the upstream ponds. This volume can be distributed into multiple ponds, located evenly at the upper parts of the sub-basin.
Annex Table 0-7 Maximum Discharge and Volume generated for each scenario

<table>
<thead>
<tr>
<th></th>
<th>Max Q (m³/s)</th>
<th>V (10⁶ m³)</th>
<th>ΔV (10⁶ m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default</td>
<td>916</td>
<td>78.17</td>
<td>-</td>
</tr>
<tr>
<td>Scenario 1</td>
<td>700</td>
<td>72.14</td>
<td>6.03</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>500</td>
<td>61.24</td>
<td>16.93</td>
</tr>
</tbody>
</table>

5. Conclusions

The objective of this research study was to develop and implement a framework for the calculation of the desired volume which will need to be withheld from retention ponds, in order to safely route generated runoff over a specified area.

Retention ponds, like other structural prevention systems, are designed to mitigate flood damages by controlling the discharge flow. This can be achieved by lowering the maximum flow and increasing the lag time. The generated FH (Flood Hydrograph) has the same flood volume and lower peak discharge values resulting in a better flood management during flood events and therefore minimising the impacts in the inundation areas.

Overall, retention ponds are effective as means of mitigating flood damages, when they are properly installed within the study area. Due to their small size, they are considered more environmentally friendly than large dams and can be created anywhere within the basin, although places at the higher elevations are deemed as better practice. The number and location of the ponds can be easily identified through the above methodology and the study areas terrain.

6. References


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