DRAFT MASTER PLAN

WATER MANAGEMENT IN THESSALY

IN THE WAKE OF STORM DANIEL

How to Address Thessaly's Water-Related Agricultural Challenges

VOLUME III: EARLY WARNING AND CRISIS MANAGEMENT

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Early Warning Systems (EWS)

In light of the significant repercussions and damage caused by the floods triggered by Medicane Ianos and Storm Daniel, it is evident that the establishment of a 24/7 operational early warning system is urgently needed. While proactive measures were taken once awareness spread, highlighting the commitment of both organizations and residents in Thessaly, the lack of centralized coordination for swift response initiatives has resulted in conflicting actions. This, in turn, introduced heightened risks and induced a sense of panic.

Ideally, an effective early warning system should comprise a round-the-clock coordinating center. Such a center would continuously receive, analyze, and process relevant meteorological information, converting it into wind and flood maps. These maps, along with corresponding early warnings for wind and flood events, should provide sufficient accuracy and spatial resolution for Disaster Risk Management authorities to make informed decisions regarding response actions. These actions could include mobile phone alerts, warnings, and evacuation plans.

The key objectives of a dependable Early Warning System are as follows:

1. Minimization of human losses (primary objective)
2. Minimization of losses in animal capital
3. Limitation of material damages

Figure 34 below sketches the four main elements of an EWS as defined by the World Meteorological Organization. These elements are:

- Risk Knowledge: Collect data and prepare risk assessments; Study the hazards and the vulnerabilities.
- Monitoring and Warning Service: Develop hazard monitoring and EW systems; Can accurate and timely warnings be generated?
- Dissemination and Communication: Do warnings reach all at risk? Are the risks and warnings understood and usable?
- Preparedness and Response Capabilities: Are response plans up to date and tested? Are local capacities and knowledge used?

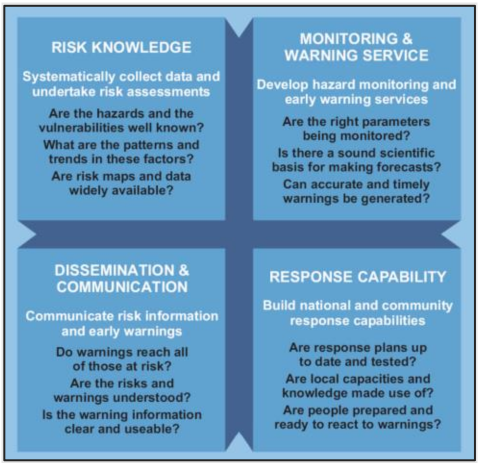

Figure 34: Four main elements of an Early Warning system (Defined by WMO)

Risk Knowledge

When addressing the complex issue of flooding, stemming from a combination of hazards such as rainfall, flash floods, and extreme tides, the creation of flood and risk maps becomes imperative. Figure 35: Inundation maps of Thessaly area on 7 September 2023 presents one of these crucial hazard products, specifically the inundation maps of the Thessaly area on September 7, 2023. These maps highlight the areas that experienced flooding on that date.

However, to provide a comprehensive overview, it is essential to develop more inclusive risk maps. These maps should integrate the hazard information with exposure and vulnerability data, offering a wholistic perspective. These comprehensive risk maps play a pivotal role in an Early Warning System (EWS), enabling authorities to identify high-risk zones. This information is crucial for informing mandated authorities about priority measures and recommending areas for evacuation.

The creation of these flood and risk maps involves the utilization of numerical models. The resolution of these maps can be adjusted based on available data, balancing refinement and efficiency. Before integration into an operational forecasting platform, these maps may undergo coarsening to ensure realistic run times while maintaining their utility and accuracy.

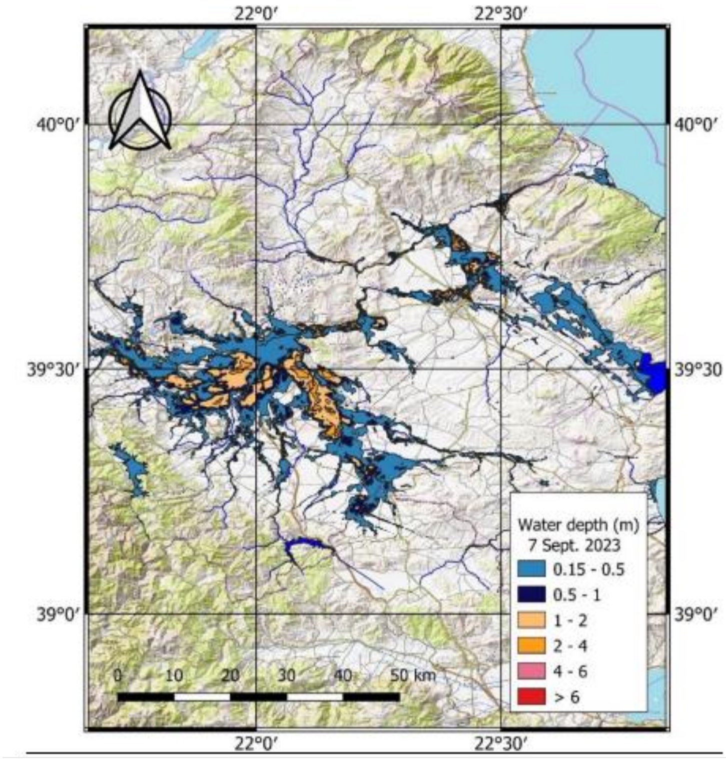

Figure 35: Inundation maps of Thessaly area on 7 September 2023

In contemporary times, achieving accurate results in flood mapping is possible through the utilization of innovative global hydrological and inundation models that rely on publicly available data as input. The noteworthy advantages of these models include their ability to be developed relatively swiftly, even in data-scarce scenarios. However, a drawback lies in their lower resolution and the elevated technical expertise necessary for their operation and maintenance. The resolution of global models is inadequate for the planning and design of flood resilience infrastructure, making it imperative to employ more detailed, customized models for such purposes.

Monitoring and Warning Service

Drawing upon the existing knowledge of natural hazard risks such as wind and flooding, the true value of an effective Early-Warning System lies in its capability to promptly and clearly communicate the predicted impacts of an impending storm to the public.

In order to achieve this, one needs:

a) Access to detailed and accurate numerical weather incl. storm or Medicane Cyclone track forecasts;

b) Dedicated, detailed and accurate numerical forecasts of local secondary conditions, i.e. pluvial and fluvial flooding;
c) An operational platform on which to automatically process inputs and outputs of the above;
d) Access to near real-time observed data, from field stations (ideally);
e) Pre-defined set of hazard- or impact-based criteria determining which type of warning should be issued for each set of conditions ('warning thresholds').

Component (a) stands out as a critical input, given that atmospheric predictions play a pivotal role not only in determining likely precipitation rates affecting the area but also in driving model simulations to predict flooding water levels. The exploration of publicly available sources in Greece and their resolution levels requires a more detailed study.

Concerning component (c), the numerical models employed in Flood Hazard and risk studies (refer to Risk knowledge) should be considered fundamental components for such forecasts. However, it is important to note that these models might necessitate adjustments, such as coarsening, before being integrated into an operational forecasting platform to ensure more realistic runtimes.

Response capability

Having established the technical framework for a future Early Warning System (EWS), equal attention must be given to the critical institutional aspect. It is imperative to clearly define and recognize the system owner and operator. This designated organization will host the computers that house the operational platform and numerical models, handling data import, simulation execution, and forecast export. Additionally, its staff will undergo training to proficiently operate and comprehend the hardware and software, interpreting and explaining results. It is noteworthy that this organization may or may not be the same entity responsible for managing any in-situ sensors.

This organization will essentially serve as the public face of the EWS, elucidating its purpose, existence, and results to both the population and the media. Further discussion and agreements within the institutional setting are essential, guided by consultations with relevant stakeholders and an evaluation of the existing legal framework, institutional capabilities, and mandates. Achieving this necessitates intensive engagement and consultation with stakeholders (See also Volume II).

Dissemination and Communication

The ultimate components of an integrated Early Warning System (EWS) can significantly impact the overall effectiveness of the entire system. Even with a 'perfect' forecast and optimal alert decision-making criteria, the efficacy of the warnings hinges on their timely dissemination and clarity, essential for prompting the desired behaviors. The institutional aspect remains crucial, as inconsistent messaging from various sources may confuse recipients and diminish their confidence in the warnings.

The previously mentioned warning thresholds and types should align with strategies for subsequent measures, such as evacuation. Clear command structures must be in place for various emergency levels, facilitating precautionary measures and organized evacuations. Establishing an effective and resilient communication system is paramount, ensuring reliable warnings to residents and coordinating diverse emergency services.

Residents and organizations within the region must be well-informed about appropriate measures when faced with an impending flood. This awareness can be fostered through the implementation of regular drills in various settings, including private and public organizations such as schools, communities, and churches.

Historically, governments have often reacted to hydro-climatic risks by responding to flood or drought emergencies without addressing the underlying causes, leading to what is termed the 'hydro-illogical cycle' (Figure 36: Hydro-Illogical2 and Disaster Risk Management Cycles (Source World Bank)). This pattern was evident during events such as Medicane Ianos and Storm Daniel.

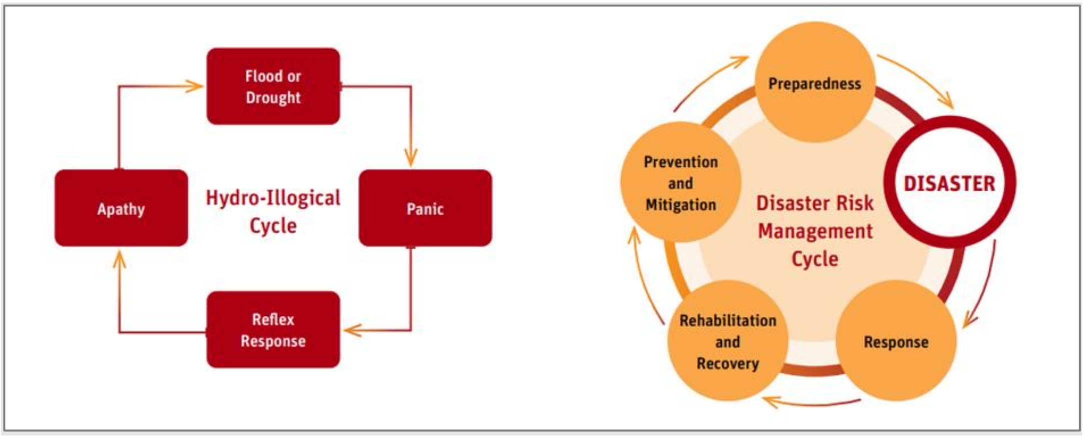

Figure 36: Hydro-Illogical2 and Disaster Risk Management Cycles (Source World Bank)

Medicane Ianos and Storm Daniel prompted a rapid and robust response, with different government agencies undertaking a flurry of activities for urgent response and relief measures. (Refer to the Fact-Finding Report for more details).

The pitfalls of succumbing to the 'hydro-illogical cycle' are widely recognized, prompting the emergence of a new paradigm that emphasizes proactive risk management, illustrated on the right side of Figure 36: Hydro-Illogical2 and Disaster Risk Management Cycles (Source World Bank). This contemporary approach to risk management, applicable to various natural disasters, is epitomized in the Sendai Framework for Disaster Risk Reduction 2015-2030, which emphasizes four key principles:

1. Understanding disaster risk;

2. Strengthening disaster risk governance to manage disaster risk;
3. Investing in disaster reduction for resilience;
4. Enhancing disaster preparedness for effective response and to "build back better."

The need for an Early Warning System for Thessaly

The Hydrological District of Thessaly spans the majority of the Thessaly province, extending into a small section of Central Greece and Western/Central Macedonia. Geomorphologically, the region presents distinct characteristics, featuring mountainous terrain surrounding the periphery and expansive plains in the central areas. The plain constitutes the largest portion of the hydrological area, bordered by mountain ranges, as illustrated in Figure 37. Notably, pronounced cliffs are prevalent in the western regions, are fewer in the plain, and become more prominent in the mountainous east.

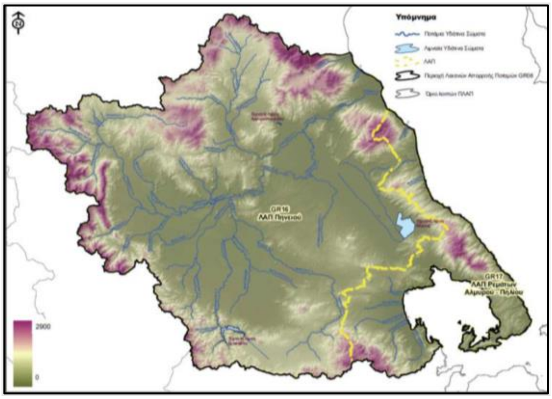

Figure 37: Morphological map of the Hydrological District of Thesally (2014)

The Hydrological District of Thessaly boasts a network of 72 rivers, collectively spanning approximately 1400 km in length. Additionally, the district is adorned with four lake water bodies covering a total area of around 45 km2. Two primary drainage basins dominate the landscape, as illustrated in Figure 38:

a) Pineios Drainage Basin (PDB) with an expansive coverage of approximately 11,000 km^2.
b) Almyros/Pelion Streams Drainage Basin (APDB) encompassing an area of about 2,000 km2.

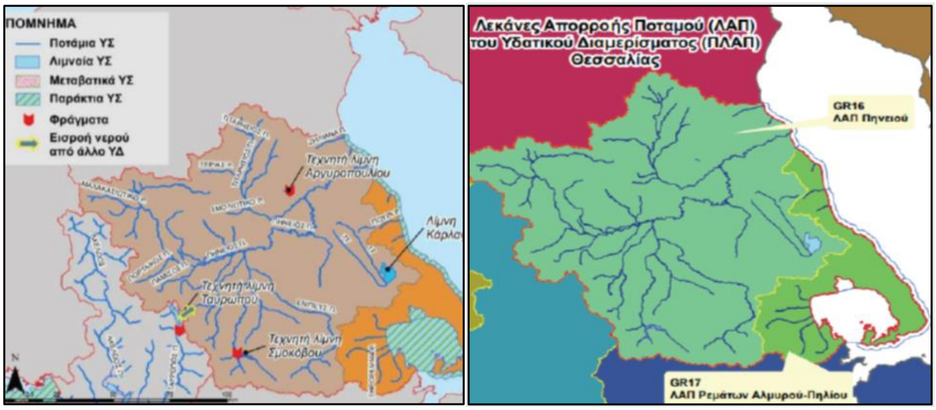

Figure 38: Main water bodies and drainage basins of Thessaly (2014)

In Thessaly, floods are typically triggered by heavy rainfall and intense storms. The hydrological attributes of mountainous regions, particularly within the Almyros/Pelion Streams Drainage Basin, are characterized by numerous watercourses with steep slopes. Existing flood protection infrastructure in the city of Volos enables swift drainage. Consequently, the basin is susceptible to flash floods, manifesting within a brief timeframe of just a few hours. In contrast, flood events in the plain areas typically unfold over an extended period due to the larger size of the drainage sub-basins and gentler slopes.

Recent events highlight the potential for floods to occur within a matter of hours in the drainage basins, emphasizing time as a crucial and decisive factor. Therefore, the Early Warning System must prioritize optimizing flood forecast time, also known as lead time. However, it is essential to acknowledge that as forecast lead time extends, the probability of inaccuracies rises. Hence, meticulous definition of appropriate actions and their timing in protocols developed through collaborative consultation between scientists and stakeholders becomes imperative.

Flood warnings often fall short in terms of reception, comprehension, and triggering the necessary responses. An illustrative instance is the 2023 flood in Thessaly, where numerous farmers expressed that they could have safeguarded their animals had they received earlier information or grasped the gravity of the situation sooner. The former aspect, 'b*eing informed earlier*,' hinges on the technical facets of Early Warning Systems. Conversely, responsibility for the latter aspect, the *'perception of severity*,' lies significantly with the message provider, necessitating the delivery of clear and universally understandable messages. This aspect also encompasses a component of the Early Warning System design, as will be explored in the subsequent discussion.

Institutional framework of EWS

When determining the institutional arrangements of the Early Warning System (EWS), it is crucial to consider the existing institutional setting. The Hellenic National Platform for Disaster Risk Reduction (HNP-DRR), coordinated by the General Secretariat for Civil Protection of the Ministry of Public Order and Citizen Protection, holds responsibility for DRR. This platform builds upon pre-existing capabilities.

Currently, the Hellenic National Platform for DRR represents the following bodies and their political subdivisions:

Ministry of the Interior

General Secretariat for Civil Protection

- Fire Corps HQs
- Independent Department of International and European Relations

Ministry of Environment & Energy

- General Secretariat for Environment and Energy
- DG for Development, Forest Protection and Forest Environment/Forest Protection and Forest Environment Directorate
- DG for Environmental Policy/Climate Change and Air Quality Directorate/Climate Change Office
- Special Secretariat for Water/Protection Directorate

Ministry of Infrastructure & Transport

- General Secretariat for Public Works/DG for Transportation Infrastructure
- General Secretariat for Public Works/DG for Water Engineering and Building Infrastructure
- Natural Disasters' Impacts Rehabilitation Directorate
- Civil Emergency Planning Office
- Earthquake Planning & Protection Organization

Ministry of Foreign Affairs

- Civil Defense Organization – Emergency Plan Policy Office

Ministry of Health

- National Health Operations Center
- Hellenic Center for Disease Control & Prevention

Ministry of Education, Research and Religious Affairs

- National Observatory of Athens
- Institute of Geodynamics
- Institute for Astronomy, Astrophysics, Space Applications & Remote Sensing

- Institute of Environmental Research & Sustainable Development
- National Center for Scientific Research “Demokritos”
- Greek Atomic Energy Commission

Ministry of National Defense

- Hellenic National Meteorological Service

Ministry of Maritime Affairs and Insular Policy

- Coast Guard HQs

Hellenic Red Cross

- Social Care Division
- Samarites, Rescuers and Lifeguards
- Nursing Division

Ministry of Culture and Sports

- DG for Administrative Support/International Relations Directorate

Budget

All collective initiatives led by the Platform are co-financed by participating parties, and individual activities are funded by Platform members based on the policy field. Presently, the Hellenic National Platform operates without a specific budget. Members of the Platform are actively seeking additional and diversified financial resources, with a priority on accessing funds through other financing instruments.

At the local level, the annual national budget allocated for prevention actions and distributed to municipalities by the Ministry of Interior, following a proposal from the General Secretariat for Civil Protection, will continue to support disaster risk reduction efforts.

A detailed high-level budget of the key recommendations and estimated budget can be found in Volume VI.

Mandate

The aim of the Platform is to facilitate the integration of Disaster Risk Reduction (DRR) into decision-making processes, primarily at the national administration level (national policies, planning, and programs) and also at the local administration level, involving the private sector and research institutions.

The Hellenic National Platform acts as a coordination mechanism supporting multi-stakeholder collaboration in implementing DRR activities within the framework of national legislation and aligned with the Sendai Framework for Action. The overarching goal is to establish a 'culture of prevention' through activities that empower society to reduce human, social, and economic losses caused by natural disasters. Special emphasis will be placed on mitigating the risk and impact of natural disasters that occur frequently and have a significant social and economic impact on the country, including forest fires, earthquakes, severe weather, floods, and landslides.

Activities

Under the co-ordination of the General Secretariat for Civil Protection, the Hellenic National Platform for DRR has initiated a series of periodical joint meetings of representatives from the relevant stakeholders.

The Platform's meetings will be:

- Setting the specific goals and priorities for the national DRR policies
- An opportunity of exchanging ideas and reviewing the contribution and efforts of each stakeholder in the field of DRR
- Identifying trends, gaps, concerns and challenges in the implementation of DRR policies
- Monitoring, recording and reporting of DRR actions at national and community levels in line with the Sendai Framework for Action
- Issuing specific measures for raising public awareness on DRR issues through public or private campaigns and in close cooperation with the Media.

A possible establishment of thematic sub-working groups, concerning specific DRR themes, may be decided upon the assent of the platform members for the facilitation of its work.

Throughout the year, communication procedures and circulation of information and relevant documents between the platform members will be carried out under the responsibility of the platform's coordinator.

Early Warning Coordination Center

As emphasized earlier, there is an urgent need to establish a 24/7 operational Early Warning System for Thessaly, based at the national level to serve Thessaly and other regions in Greece. Within this national system, a Coordinating Center should be established with the continuous responsibility of receiving, analyzing, and processing meteorological and flood-related information. The Coordinating Center must possess authoritative powers, essential expertise, and tools to conduct comprehensive analyses, assess risks, and make informed decisions regarding appropriate responses. It is crucial for the Center to engage in effective and proactive communication with relevant regional and local entities.

The Coordinating Center should have seamless access to all relevant flood forecasting information, including meteorological and hydrological data such as surface water levels, discharges, dam levels, and fillings. Local monitoring services, particularly from the newly established Water Management Organization in Thessaly, should promptly relay real-time data to the national Coordinating Center, which must be adept at automatically processing and formatting the information. The National Observatory of Athens will play a pivotal role in providing essential forecasts on storm fronts, anticipated rainfall volumes, and actual registered rainfall data, vital for assessing flood risks well in advance. Equally crucial are the roles of operators from the Thessaly-based Water Management Organization, managing hydrological stations and dam operators overseeing levels and fillings. The monitoring and data storage and transfer systems must be robust to ensure reliability.

The Early Warning Center(s) need the tools and expertise to make accurate predictions of flood risks, instruct relevant regions, and coordinate the response of emergency services. For this purpose, reliable flood prediction models specific to Thessaly River basins should be developed based on the hydrological model for the implementation of the Master Plan.

It is recommended that the Early Warning Coordination Center be centralized within the General Secretariat for Civil Protection due to the expertise required and the investments in staff and tools. However, this does not mean that all coordination will take place at the central level. Once the national Early Warning Center has transmitted predictions and warnings to the regional and local levels, further coordination of proactive, precautionary measures, as well as response measures, must be implemented by these regional and local authorities, mandated by the legal framework for Disaster Risk Management.

Protocols should be developed for various states/levels of emergency to ensure proper coordination between local, regional, and national government bodies. The objective is to disseminate clear (non-conflicting) information and action perspectives to the population in a timely manner. The development of these protocols must be a joint activity of the General Secretariat for Civil Protection (lead) and the regional and prefectural governments.

Recommended organization / governance

1. Establishment and/or strengthening of the National DRM and Early Warning Center within the General Secretariat for Civil Protection. This Center will be responsible, among other things, for the smooth operation of the Early Warning System and will closely collaborate with meteorological services.
2. Development of accurate flood models and risk maps as part of the predictions of flood risks to instruct the relevant regions and coordinate the response of the emergency services.

3. Establishment of the regional Water Management Organization (WMO) for Thessaly with executive powers. (See **Error! Reference source not found.**) The Thessaly WMO will be responsible for all aspects related to Integrated Water Resources Management, including the monitoring and data collection for the National DRM and Early Warning Center.
4. Establishment of substations in municipalities and communities prone to floods (Annex 5. EWS: Proposals for organization
5. Formulation of Early Warning System protocols Annex 6. EWS: Effective Communication and Messages) entailing clear delineations of roles, responsibilities, and action plans achieved through collaborative consultation with both scientists and stakeholders (Annex 1. Infrastructure and early warning systems).

Recommended General Planning

1. Assessment and enhancement of the current observation network, encompassing topographic, geological, hydrometric, pluviometric, and meteorological components.
2. Evaluate the sufficiency of the present observation network concerning geographical location, density, and reliability. A denser and technologically advanced observation network enhances the reliability of the new Early Warning System. It is imperative to optimize the geographic placement of new stations, particularly in regions affected by the recent floods.
3. Establish a consolidated database that incorporates data from the current observation network.
4. Evaluate, develop and/or and enhance hydrological/hydraulic models.
5. Evaluation of the reliability and accuracy of meteorological forecasts in collaboration with the meteorological service.
6. Assessment and upgrade of information technology (IT) infrastructure to ensure rapid data collection and analysis, model operation, and distribution of warnings.
7. Assessment of the technical capacities of institutions and staff involved for development
8. and implementation of flood models and operational platforms.
9. Outline technical recommendations on options to meet the technical needs (staff capabilities, hardware/equipment, and others) required;
10. Creation of backup systems.
11. The backup systems will be less advanced and expensive than the main system and will be used by municipalities susceptible to floods in case of need.
12. Design of EWS in parallel with the design of flood protection measures such as permanent infrastructure and room for the river.

Both ongoing and prospective flood protection initiatives must be considered in the design of the new Early Warning System. These factors are incorporated into hydrological/hydraulic models, contributing to the identification of areas at elevated risk of flooding. Anticipated flood protection measures are likely to impact data parameters, including land use, vulnerability, and population exposure to floods.

Recommended Technical Design for ‘ready-set-go’ methodology.

- Evaluate and enhance the existing observation network.
- Establish a unified database for critical data, including hydro-meteorological information.
- Assess and improve hydrological/hydraulic models.
- Evaluate the reliability and accuracy of meteorological forecasts.
- Assess and enhance the information technology (IT) infrastructure.
- Develop backup early warning systems.
- Simultaneously design Early Warning Systems alongside future flood protection measures, such as permanent infrastructure and river space allocation.
- Implement the '*Ready-Set-Go*' methodology.

Enhancing the effectiveness of the Early Warning System involves the progressive issuance of warnings at various time intervals preceding the flood. Each message serves to prompt specific actions in accordance with established protocols, thereby optimizing the impact of the final action, should it be executed.

- Step 1 - Flood alert: Encompassing an extensive geographical expanse, prompts stakeholders to be prepared, initiating diverse preparatory actions such as revoking approved time off for essential personnel and conducting system checks. In the Pinios drainage basin, this signal may be issued 1-3 days before the flood, whereas for the Almyros/Pelion Streams Drainage Basin, the lead time is anticipated to be shorter, for example, 1 day.
- Step 2 - Flood warning: Signifying preparedness (set), Step 2 boasts enhanced geographical precision compared to Step 1. Potential actions triggered at this stage may involve instructing citizens to stay at home and remain attentive for subsequent messages from authorities. This step is typically communicated 3-12 hours before the impending flood.
- Step 3 - Severe flood warning: Approximately 1-3 hours before the flood, a decisive call for immediate action (go) is made, often involving evacuation of settlements. This message is typically issued when the probability of flooding is significant, and the geographical determination is highly accurate.

Recommendation Technical Details

Hydrodynamic models are recommended for determining rainfall, flow, and water level values associated with various flood magnitudes across the entire study area. These models will also assess the impacts of each flood scenario.

The Early Warning System will operate in brief time increments, such as 5-10 minutes, for the earliest possible forecasting of flash floods. In each time step, rainfall data from radars and rain gauges will be collected and compared with meteorological model forecasts from the meteorological service. Subsequently, thorough analysis and additional rainfall prediction (nowcasting) will be executed to formulate rainfall scenarios. These scenarios will be compared with rainfall values associated with varying flood levels.

Upon surpassing rainfall thresholds, considering antecedent events, the initial warning level (ready) will be activated. This will prompt hydrological calculations for all rainfall scenarios to assess runoff and water levels. These calculations will be compared against critical thresholds, and if surpassed, the second warning level (set) will be issued. Following this, hydrodynamic calculations will be conducted to ascertain flow and water levels at specific stream points, comparing them with corresponding critical values. Upon exceeding these thresholds, the third warning level (go) will be issued.

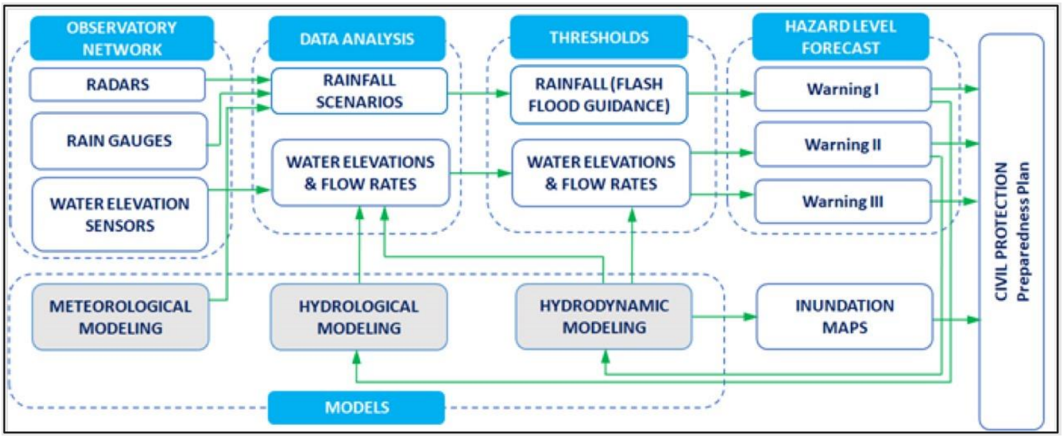

Figure 39: Methodology of example integrated EWS (Anastasios I Stamou, 2018)

Communication

The warning system and communication channels used during Storm Daniel proved ineffective. Despite the anticipation of a severe storm, numerous populated areas were caught off guard by floods, resulting in the loss of life and drowning of hundreds of thousands of farm animals unable to be relocated in time.

Instances of communication breakdowns are unfortunately not uncommon in flood disasters. The July 2021 flood disaster in Germany, which resulted in over 180 fatalities, is a notable example where communication faltered. An online survey revealed that about one-third of residents did not receive any warning. Among those who did, 85% were unaware of the severity of the impending flooding, and 46% lacked situational knowledge regarding protective measures. Flood damage destroyed communication infrastructure, including cell towers, and some villages were hesitant to activate sirens.

In Thessaly, there is a need to diversify communication systems for public warnings. While smartphone apps are valuable, their effectiveness may be compromised at night unless silencing functions can be overridden. Power failures can disable cell phone towers, making it challenging for civilians to charge their phones, and telephone networks are prone to overloading during emergencies. In order to address these challenges, alternative communication and warning systems should be established, ideally in each village and town neighborhood, including sirens, loudspeakers, and radio transmissions.

A request should be issued to the Radio Amateur Association of Greece (RAAG) to explore potential roles. RAAG is a national non-profit organization for amateur radio users in Greece and is active in emergency radio communications (EmComm) in cooperation with local radio associations and societies, under the name HARES or Hellenic Amateur Radio Emergency Services.

As a general rule, all disaster preparedness and response communications with the public need to be concise and direct to ensure that information from the Early Warning Coordination Center reaches recipients accurately. Messages should be 100% unambiguous so that civilians in affected areas know exactly what to do. The introduction of risk levels (e.g., green, yellow, orange, and red) will help improve awareness of the situation.

The General Secretariat for Civil Protection has developed tools and instructions for emergency preparation and response, but these materials are not sufficiently known and effective. In the days leading up to Storm Daniel, communications from the General Secretariat were largely ignored or not followed-up on. Therefore, the Early Warning Coordination Center must adopt a more proactive communication strategy and actively liaise with regional and local stakeholders in flood response.

Effective Communication of Messages and Actions:

Surveys to determine action protocols:

1. Surveys will be conducted in various groups during EWS design to help determine how information is transmitted so that messages a) reinforce individual flood risk perception and b) contain all the information required to take sufficient measures.
2. Continuous training of EWS personnel and volunteers (e.g., simulation exercises).
3. Raising awareness (e.g. via expert presentations, school training, serious gaming, videos, leaflets)

Concrete examples of effective communication and messages actions can be found in Annex 6.

Crisis Management

The fragmented water governance structure in Thessaly (Volume II), became evident during the emergency situation triggered by Storm Daniel and the subsequent post-disaster flood recovery. The lack of an evacuation plan or strategy for rescuing civilians and livestock, coupled with the absence of provisions for their basic needs, emergency supplies, or equipment to mitigate the floods, underscored the shortcomings. Furthermore, the absence of a centralized coordination unit with the requisite authority and expertise hindered the imposition of effective measures for post-disaster flood recovery.

Organization

The findings of the HVA Fact-Finding Mission highlight the urgent need for a central management unit for emergency and flood recovery measures. Similar to the organization of early warning, there is a pressing requirement for crisis management protocols that clearly outline roles, responsibilities, and courses of action, specifying the circumstances under which they apply. Such a unit should have the powers and expertise to enforce the right measures once a flood disaster occurs. These protocols should be collaboratively formulated by the General Secretariat for Civil Protection (as the lead authority) and the regional and prefectural governments. They must be designed for various levels of emergencies and facilitate the swift augmentation of emergency response capabilities.

In general, a layered structure proves most effective, entailing various coordinating units at different governance levels. It is crucial to ensure that decisions are made at the appropriate level to efficiently organize and direct emergency services, including fire brigades, police units, the national guard, hospitals, rescue teams, and contractors.

Supplies

Enhancing disaster preparedness involves establishing repositories containing essential machinery for emergency repairs and debris removal, boats for rescue operations, and sandbags for distribution to safeguard vulnerable areas in dykes and protect houses and vital infrastructure.

A comprehensive list of essential equipment and materials for diverse interventions in crisis management was developed as part of the project 'Development of operational strategies and guidance on tackling consequences of extreme rainfalls and flash floods,' co-financed by the EU. The Greek General Secretariat for Civil Protection was one of the consortium partners. The project provided overarching tactical guidelines applicable to emergency situations. It is imperative to disseminate this document to local stakeholders in crisis management through civilian drills (farmer cooperatives, schools, church communities, pensioners, etc.) and take measures to ensure the implementation of all guidelines.

Available institutional and technical capacity

The above-described steps towards the establishment of DRM capacity and an EWS implicitly assume that the necessary institutional and technical capacities are sufficiently available. The conclusion from a more detailed assessment of these capacities might reveal however that this would not be the case and that the sustainability of the proposed EWS cannot be sufficiently guaranteed with current levels of capacity in place. This could be the case if from the DRM or EWS assessment it appears that;

1. Flood modelling expertise is not sufficiently guaranteed at the national level and de-central level to develop, operate and maintain flood models;
2. If no or insufficient capacity is available to work with complex operational system;

If that situation would occur alternative approaches might have to be developed to develop these capacities.

A few guidelines can be given for the development of a strategy to improve technical and institutional capacities to sustainably develop and implement flood models and operational procedures.

- The strategy to improve technical and institutional capacities for Thessaly should be well aligned with a nation-wide strategy based on current forecasting procedures and practices;
- Considering that improvement of the technical and institutional capacities, as well as the knowledge infrastructure, takes time and funding, priority actions should be defined for the short term 1-2 years and medium term 3-4 years. These actions should take existing well-established procedures and workflows in Greece as a starting point and improve and build upon them in a step-by-step manner.
- In order to ensure that institutional improvements and improved technologies can be absorbed into the daily procedures of relevant institutions, a phased approach is advised. High impact measures that are relatively easy to implement and that can be introduced at the short term are advised, while measures taking more time and revision of operational procedures get implemented at the medium and longer term when the necessary technical and institutional capacity has been created.
- It is of primary importance that reliable flood hazard maps are established for various levels of severeness (different return periods). With the existing technical capabilities in Greece this probably requires support from external experts. Which software tools are used to construct these maps is of less importance at this stage, as long as the products – the hazard maps – are reliable and prepared in such a way that they can readily be absorbed into operational procedures in Greece.
- Follow a step-by step procedure and ensure that new technologies/methods:
    - align well with existing methods and workflows,
    - are robust, scalable and sustainable in terms of licensing and software/hardware requirements,
    - are readily adopted in the operational procedures,
    - receive longer term technical support to assure effective implementation.

Apply a uniform approach for flood modelling and forecasting across Greece to allow for efficient capacity building programs to be developed at the national level. This also allows easier exchange and rotation of staff between relevant organizations (national to regional, regional to national and regional to regional). The country wide application of uniform tools also allows for a better negotiation position for cheaper software licenses and support contracts.

While data gaps might be a challenge, make optimal use of available global and earth observation data in regions that currently lack access to (high quality) data.

For all technical implementation projects ensure that longer term support with regards to IT and software is included that warrants robust adoption into operational procedures and sustainability of results, technologies and other products. For the measuring stations maintenance protocols need to be prepared to guarantee reliability.

Ensure sufficient staff is available to avoid undermining the improvement of human and institutional capacity building.

Improving measures to address existing data scarcities and enhancing the temporal and spatial accuracy of flood information for early warning and early action in Thessaly can serve as a model for other regions. We propose a method using updated and validated flood maps, which spatially indicate flood hazards and, if necessary, issue warnings based on measured or forecasted hydro-meteorological conditions (rainfall and water levels). This approach can easily be scaled up across the country or even the wider region.

Considerations regarding flood modelling tools

There has been no systematic assessment of the flood models currently used in Greece and the software packages for hydrological modeling and flood modeling on which these models are based. It is believed that the existing models, created with HEC-RAS, and the information collected for this purpose could serve as a basis for further application in the Master Plan. However, the final selection of software packages should be based on a more detailed assessment of existing models and a uniform application strategy developed as part of a national approach, rather than being determined by various project implementing organizations.

To facilitate efficient future capacity building and facilitate the exchange and rotation of staff between relevant organizations (national to regional and vice versa and between regional agencies), a software policy should be developed. This policy would standardize approaches for flood modeling and forecasting, defining previously agreed standards and Terms of Reference to achieve a more uniform approach.

Various selection criteria for these software packages could be considered. The main consideration should be avoiding scenarios where there is no support, and the software becomes non-functional after simple technical problems. Key selection criteria include:

- Ongoing costs of purchase and licenses;

- Existing experience in Greece;
- Available helpdesk support;
- Number of users;
- Whether it is protected or open source;

The following tables 8 and 9 provide an overview of different software packages for hydrological and flood modelling respectively.

Hydrological models simplify real-world systems (e.g., surface water, soil water, wetland, groundwater, estuary) to understand, predict flows, and manage water resources.

Product	Developer	Home Market	Users	Open source	Free	Helpdesk	Lumped/gridded	Other criteria
HEC=HMS	US Army	US, Global	>50.000	No	Yes	Public website	Lumped	Well-established, Used a lot in Africa. Link to forecasting
MIKE-SHE	DHI	DK, >30 countries	20.000	No	No	Yes	Gridded	Commercial, well-established
IFAS	ICHARM	JP, many (developing countries)		No	Yes	Yes	Gridded	Incl. forecasting component
HBV	SMHI	SW, >30 countries	20.000	No	Yes	Yes	Lumped	Well-established
Wflow	Deltares	NL, >20 countries	500	Yes	Yes	Informal / GITHUB	Gridded	Continued development, fast model generation, open data
LSTM	Universities	>20 countries	5.000	Yes	Yes	No	Machine Learning	Mainly scientific approach

Table 8: Overview and comparison of hydrological software packages

Flood modelling tools predict fluid movement and water levels in either a 1D (single dimension) scenario within a channel or conduit, where the single dimension aligns with the direction of the channel or conduit, or a 2D (two dimensions) scenario, typically across a floodplain or land surface. In the 2D scenario, the two dimensions of movement encompass any direction on the horizontal plane.

Product	Developer	Home Market	Users	Open source	Free	Helpdesk	Other criteria
MIKE FLOOD	DHI	DK, >30 countries	20.000	No	No	Yes	Support in the region, Commercial
InfoWorks ICM	Innovyze	US, AU, UK	30.000	No	No	Yes	Closed system, high cost, commercial
HEC-RAS	USACE HEC	US	80.000	No	Yes	Public discourse website	Free Model, Limited 2d functionality
D-HYDRO	Deltares	NL	20.000	Yes	No	Yes	Low support costs, additional functionality paid on demand

SWMM	USEPA	US	50.000	Yes	Yes	No	Flexible software, no 2d functionality
Flood modeller/ TUFLOW	JACOBS CH2M / BMT	US, AUS	5.000	No	No	Yes	Limited 2D functionality
OpenFlows FLOOD	Bently ststems	US, IR, CHN	5.000	No	No	Yes	Commercial

Table 9: Overview and comparison of 1D2D flood modelling software packages

The purchase and support costs of various software packages depend on specific training requirements and other commercial criteria such as the number of users[26], making direct comparisons challenging. If the criteria include low costs, continued support, and prevailing use and experience in Greece, HEC-HMS/HEC-RAS software packages could be recommended. If other criteria, such as the speed of model generation or support costs, are considered, different software packages could be explored. The crucial aspect is not the specific software tools used to construct flood maps but ensuring that the products—hazard maps—are reliable and prepared in a way that readily integrates into operational procedures in Greece.

Training methodology

While building a hydrological model is often viewed as a one-time task, it is essential to recognize that hydrological models need continuous improvement and updates with new data to support well-informed decision-making. This is particularly crucial in a world experiencing rapid changes, such as:

- Climate change leading to unprecedented extreme rainfall;
- Land use changes stemming from deforestation;
- The construction of new dams and reservoirs.

All these factors influence the hydrological behavior of catchments, and these changes must be considered when using the models for real-time forecasting or planning purposes. A continuous development cycle is necessary, aiming to improve both the data and models consistently. Multi-year plans, along with corresponding multi-year financing, are required to develop the models and build up the capacity in the team to achieve this goal.

[26] "The estimate of the number of users are rough estimates based on information retrieved from the software web-pages, user forums, google hits etc.

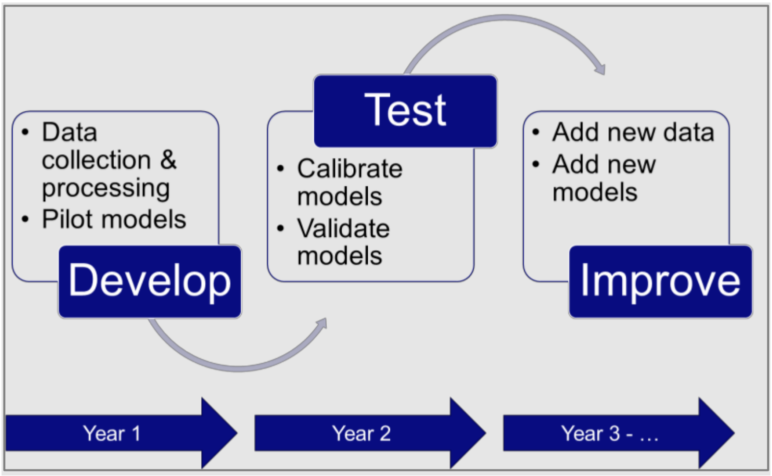

Figure 40: Schematic overview of continuous development.

For model development, it is recommended to tender the process using a guided modelling approach, also known as collaborative modelling, where Greek staff is actively involved in the development process.

The training program implementation should enable full participation and ownership by the involved Greek staff. This program should encompass both official training sessions and hands-on learning-by-doing experiences.

Planning of EWS implementation

Considering the urgency of the Early Warning System (EWS) implementation, it is imperative that activities commence without delay. Before procuring equipment and initiating training activities, a comprehensive feasibility study is necessary. This study will identify the system's detailed requirements, design, and training needs. It will be informed by consultations with national and regional stakeholders, alongside an assessment of the current data availability and the capacity to implement, manage, and operate the system effectively.