



WES-BCA
Water and Environment Support -
Biodiversity and Climate Action
in the Neighbourhood South region



Funded by
the European Union

WES-BCA Regional Training & Study Tour

“Adaptation measures for flood and storm water management”

21-24 April 2026, Nice, France





23 April 2026 at 10:30

Sheraton Hotel Nice

WES-BCA

Regional Training and Study Tour

Adaptation Measures for flood and storm water management

Activity Number: C1_REG/ST-6

Hybrid and Non-Structural approaches and their role in flood/ stormwater management

Presented by:

Dr. Ioanna ZALACHORI, Senior Flood Expert, LDK Consultants S.A.



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Integrated Flood Management



Paradigm Shift from “**flood control**” towards “**flood management**”.

“Flood management consists in accepting that floods as part of river’s natural life”:

- ❑ shifting from a *re-active* to a *pro-active* flood management strategy,
- ❑ balancing *flood risk* to *sustainable development* and
- ❑ from *ad-hoc flood control* to *integrated flood management*.



Integrated Flood Management (IFM)

Integrated Flood Management (IFM)



IFM maximizes net benefits of social development next to river, while minimizing life and property loss from flooding

Integrated Flood Management consists in a few phrases:

- **adopting** a **basin approach** to flood management,
- **bringing** a **multidisciplinary approach** in flood management,
- **reducing** vulnerability and risks due to flooding,
- **enabling community involvement**,
- **preserving** ecosystems.

Basin Approach

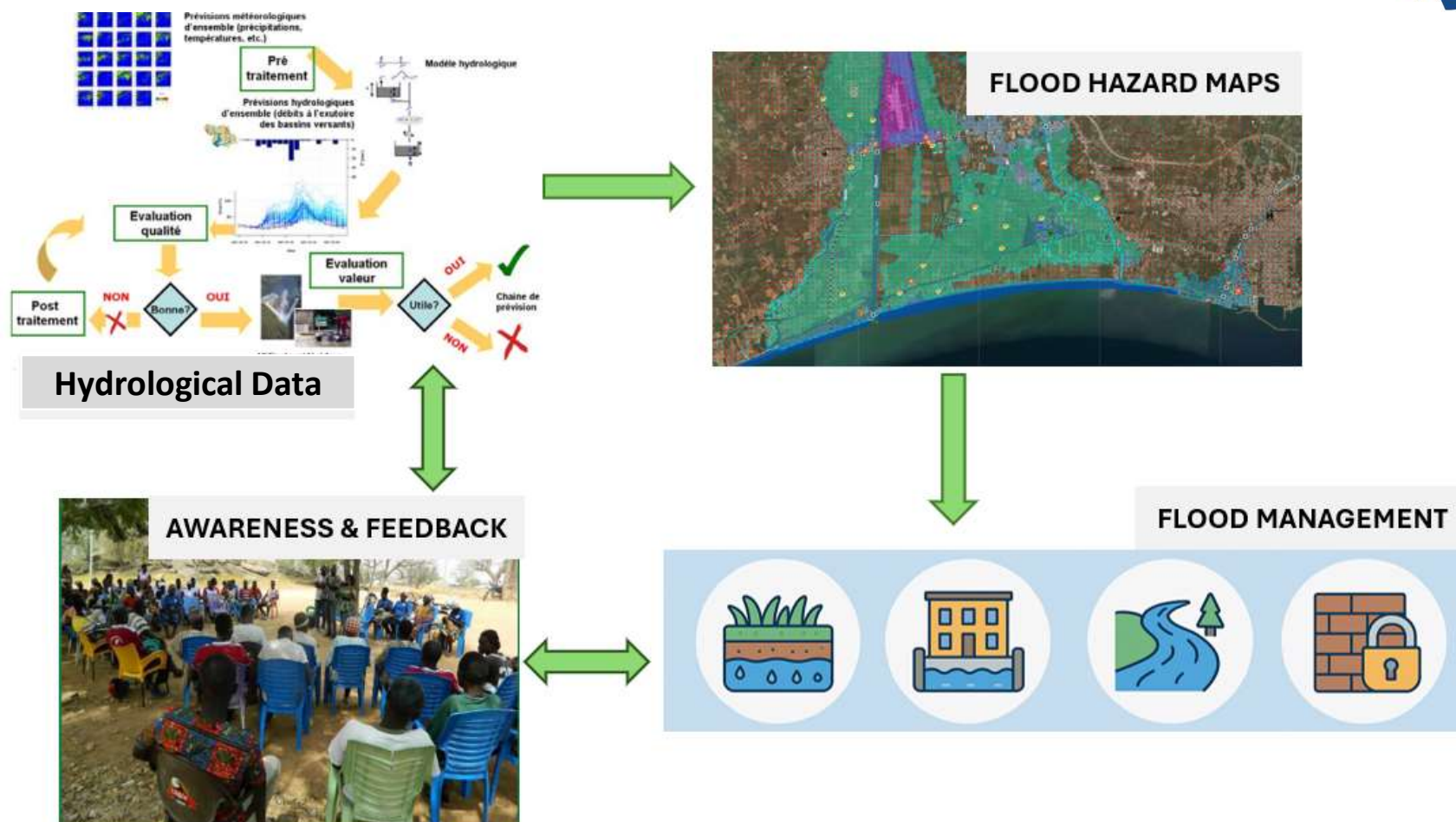


The *EU Directive 2007/60/EC* (“Floods Directive”) drifts from:

fragmented flood risk reduction approach to an **integrated** approach in basin level,

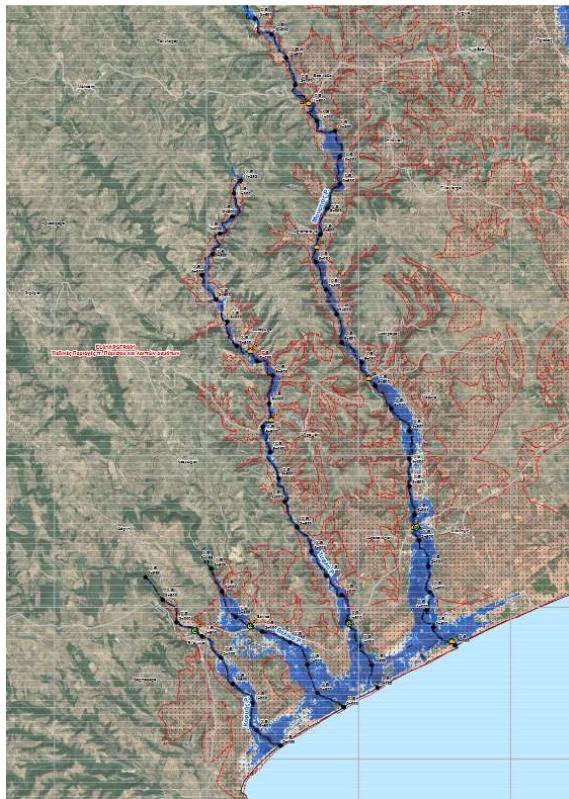
where **hard flood protection measures** are complemented by **structural and non-structural measures** that mitigate flood impacts.

Basin Approach with an example



Basin Approach with an example

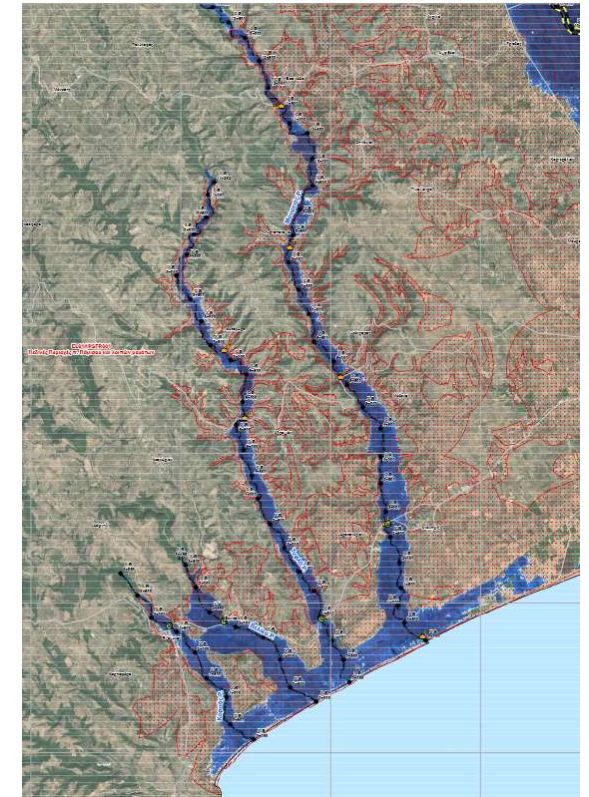
Design Return Period Choice



FHM – Max Depth -T50 years



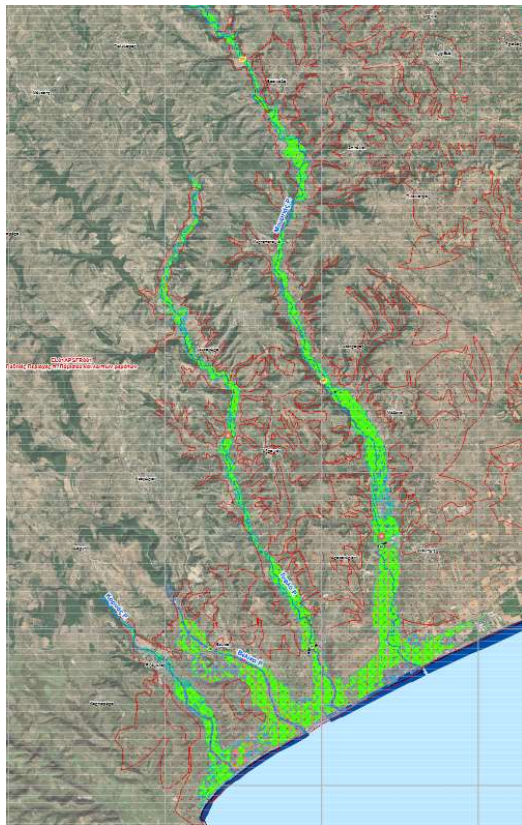
FHM – Max Depth -T100 years



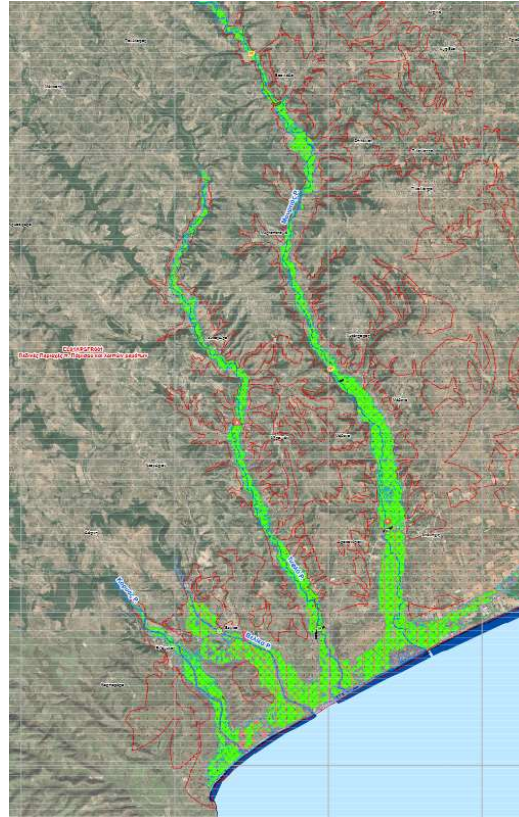
FHM – Max Depth -T1000 years

Basin Approach with an example

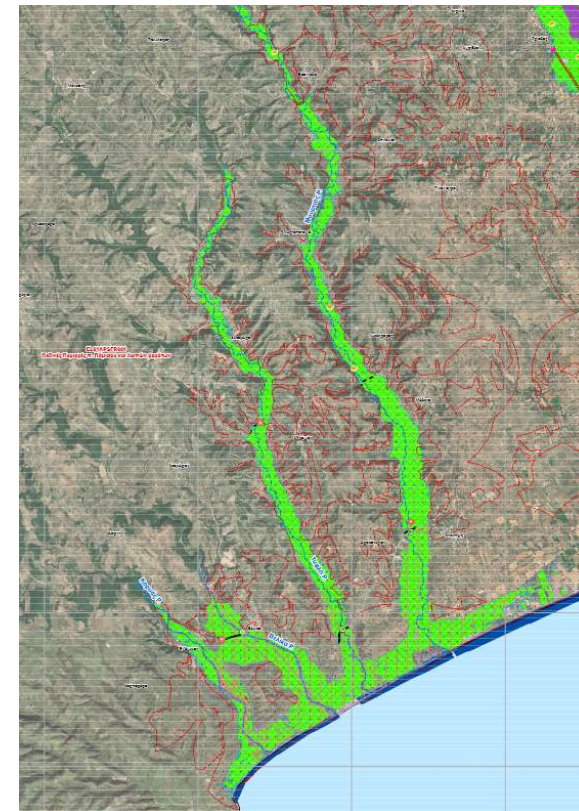
Manage Residual Risk



FRM -T50 years



FRM -T100 years

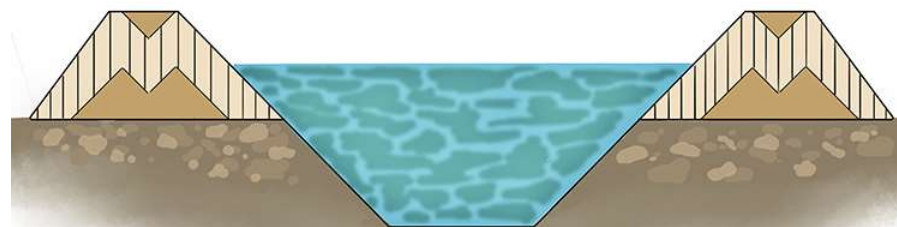
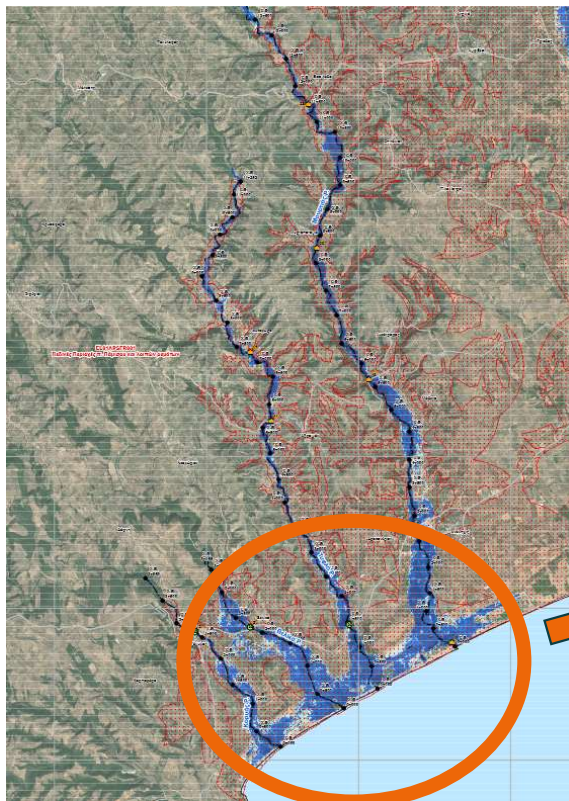


FRM -T1000 years

Basin Approach with an example

Flood Management Options

Option A: Levee or Embankment



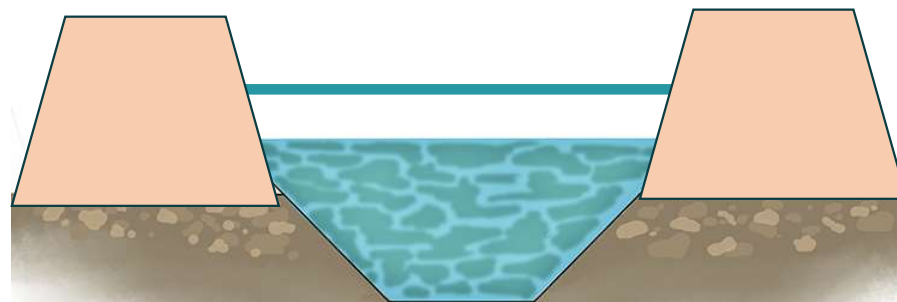
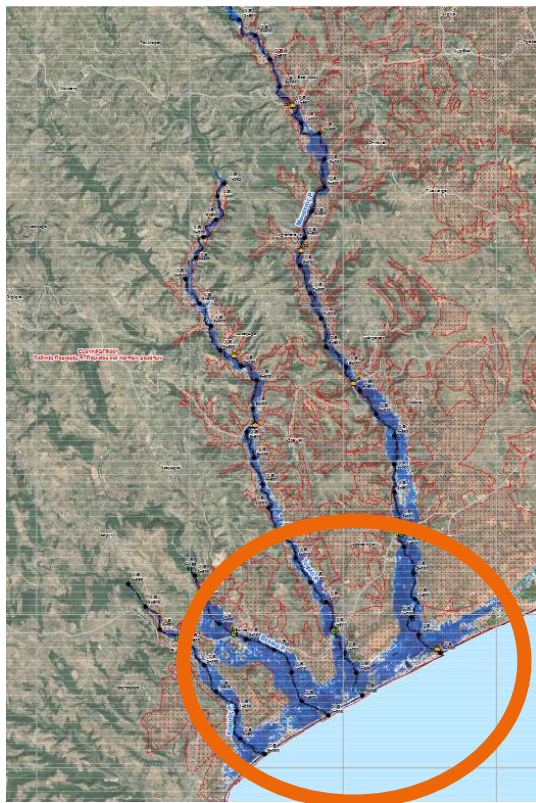
Source: <https://mammothmemory.net>

FHM -T50 years

Basin Approach with an example

Flood Management Options

Option A: Levee or Embankment



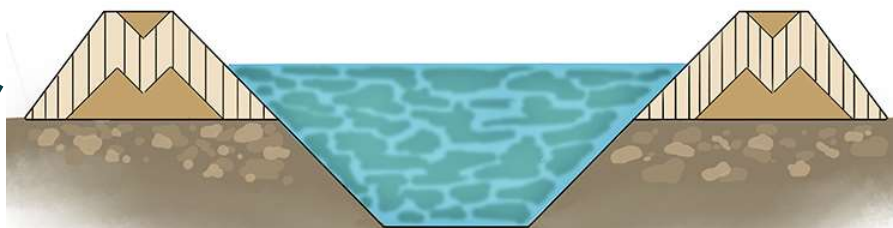
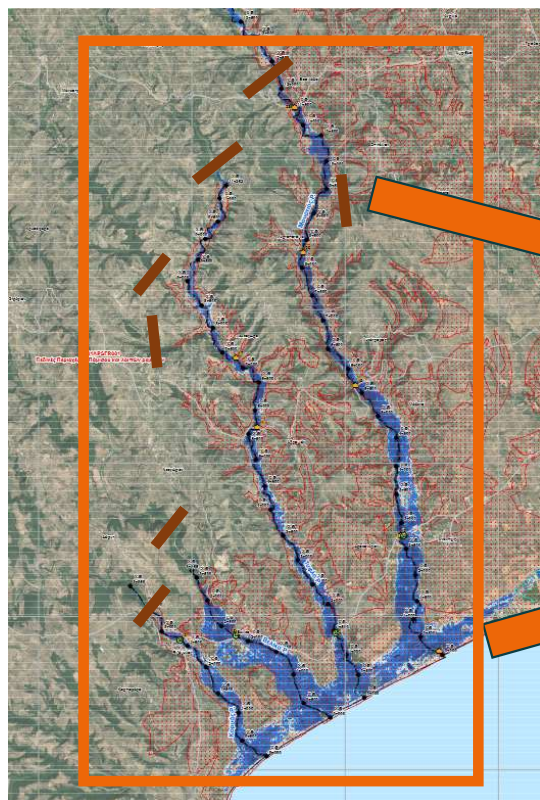
- ☐ costlier flood protection works,
- ☐ more significant environmental imprint,
- ☐ larger spatial imprint / social impact.

FHM -T100 years

Basin Approach with an example

Flood Management (Hybrid) Optionsc

Option B1: Embankment + Check Dams (Hybrid Approach)



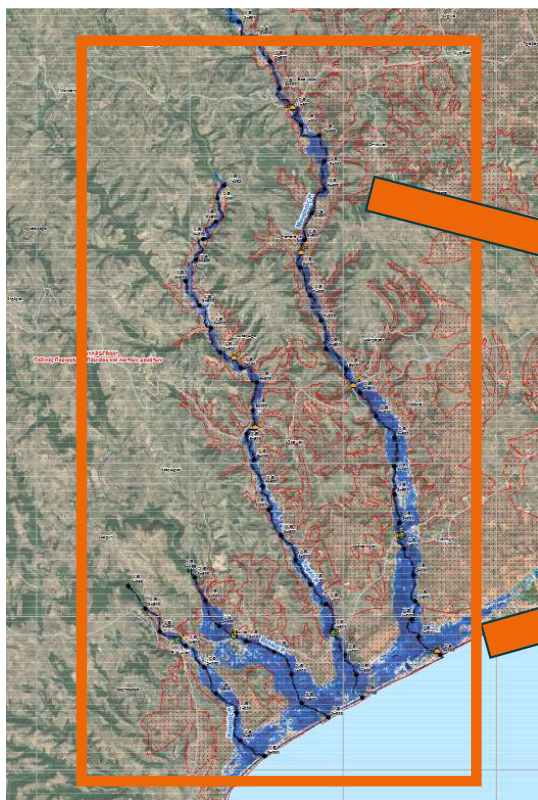
FHM -T100 years

- ☐ water retention and sediment trapping,
- ☐ smaller environmental & spatial imprint.

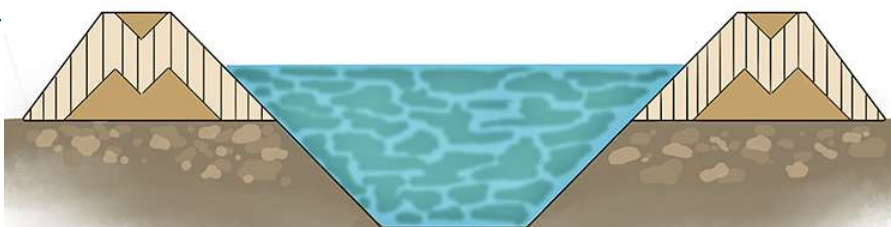
Basin Approach with an example

Flood Management (Hybrid) Optionsc

Option B2: Embankment + Terracing



FHM -T100 years

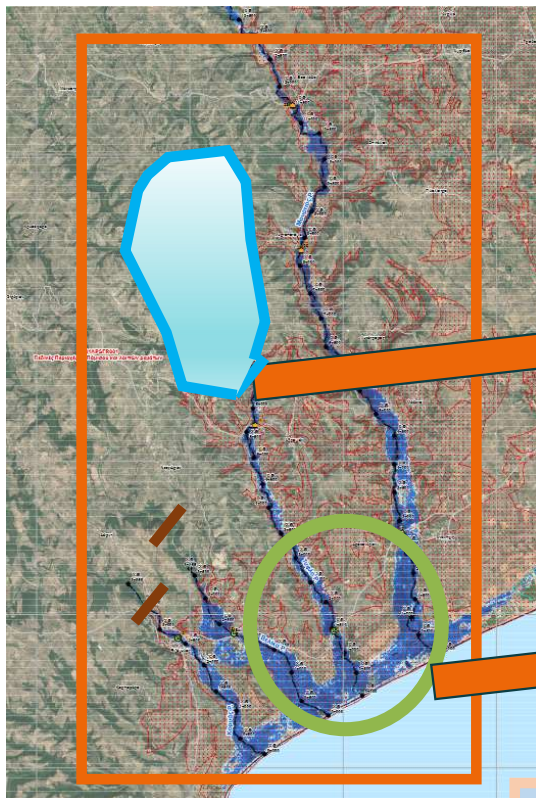


- ☐ water retention and sediment trapping,
- ☐ smaller environmental & spatial imprint.

Basin Approach with an example

Flood Management Options

Option C: Water Reservoir + River NWRMs (Hybrid Approach)



FHM -T100 years

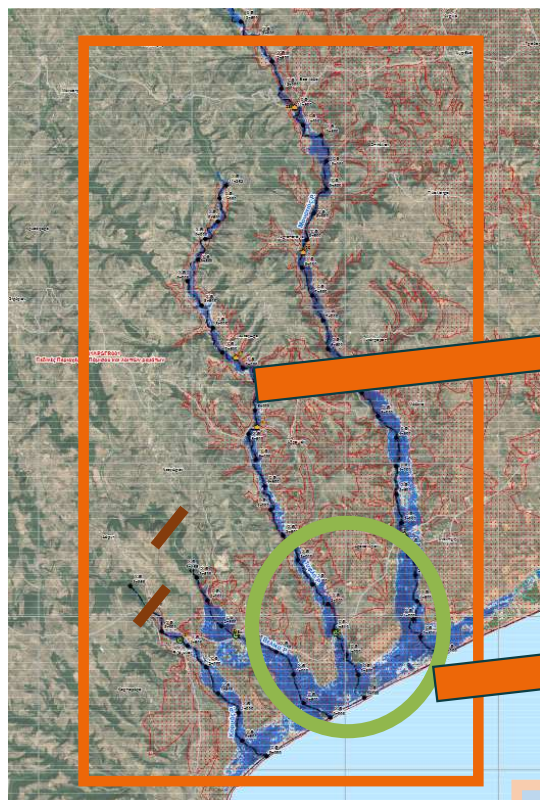
- ☐ water retention upstream,
- ☐ Ecosystem enhancement downstream.

Source: CA Dept. of Water Resources

Basin Approach with an example

Flood Management Options

Option D: Floodplain Reconnection + River Canalization



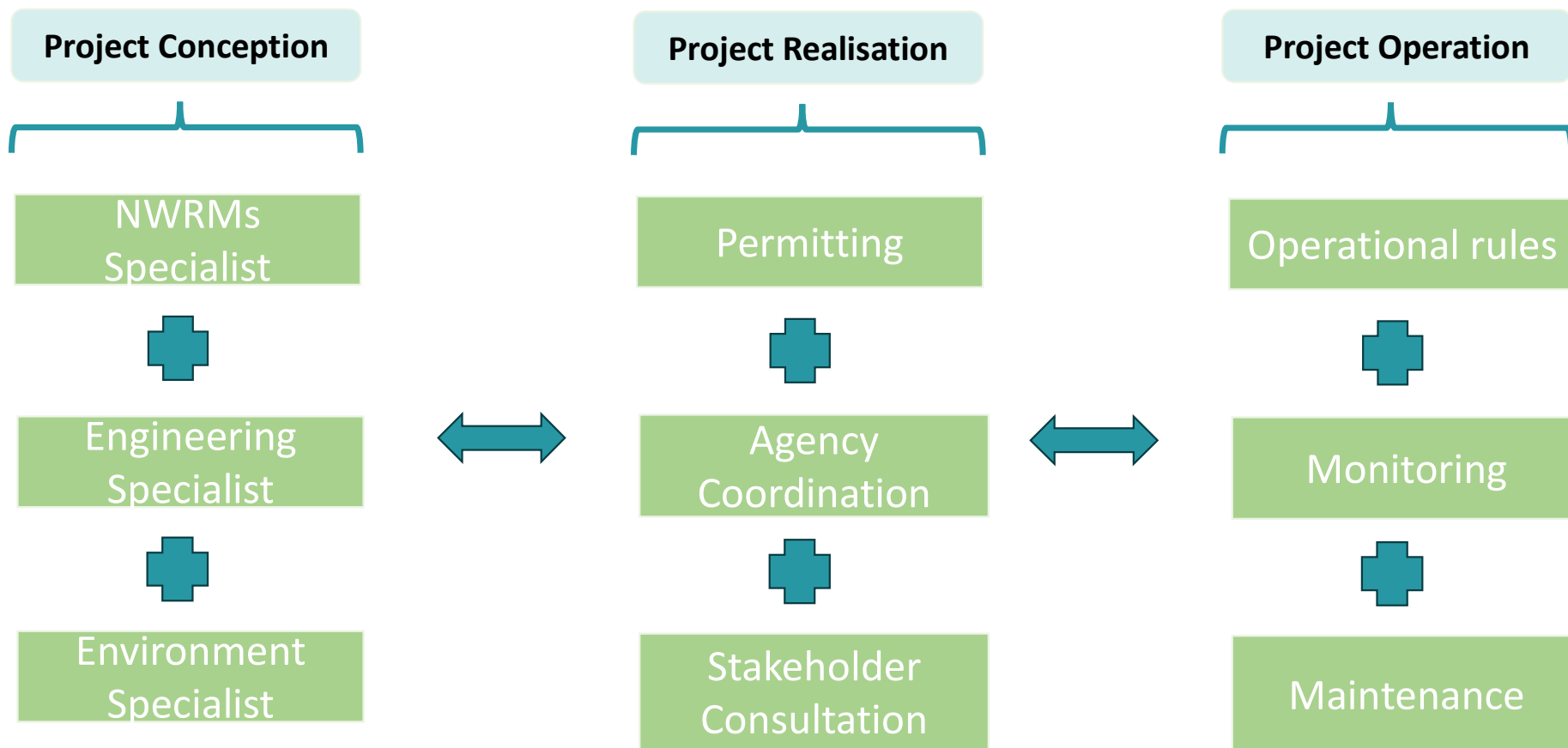
FHM -T100 years

- ☐ water retention & Ecosystem enhancement upstream,
- ☐ Water level and flow control

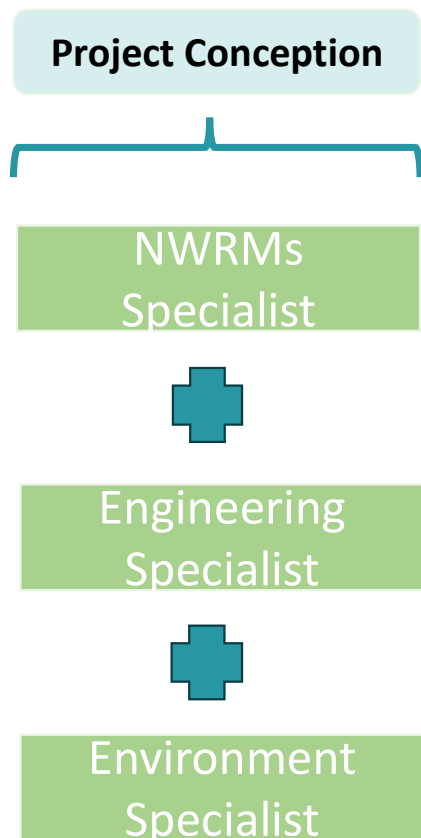
Multidisciplinary approach



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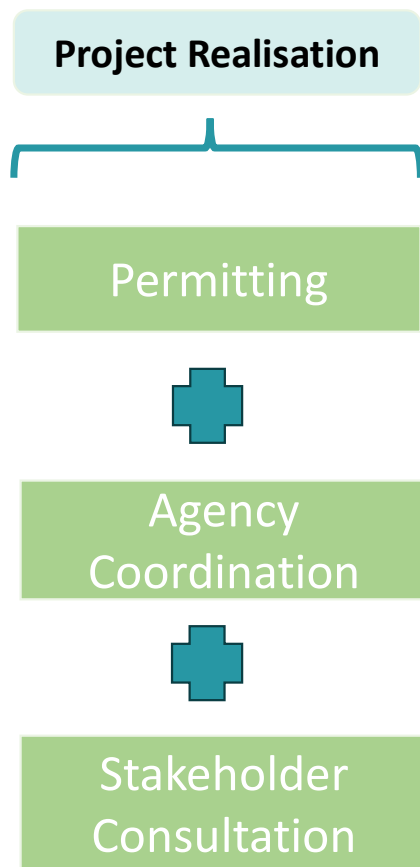
Multidisciplinary approach



Hybrid methodology includes the following steps:

- ✓ **modelling** NWRMs individually, by quantifying peak attenuation, volume reduction, lag time, etc
- ✓ **check** conventional measures size based on modified hydrographs and modify conventional measures dimensions (e.g. pipes, tanks, levees, culverts, etc).
- ✓ **CAPEX/OPEX calculations** based on modified conventional measures design,
- ✓ **calculate Cost Benefit Ratio (CBR)**, by adding all individual co-benefits in order to capture full hybrid value.
- ✓ **run sensitivity analysis** based on different climate variability scenarios and performance levels.

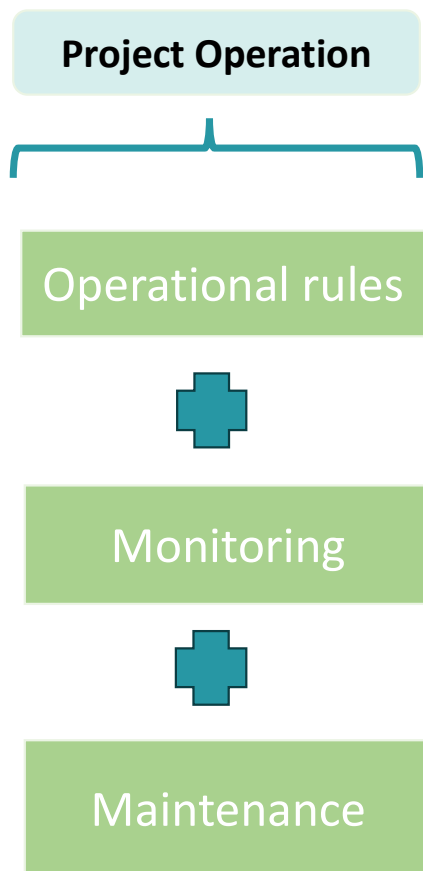
Multidisciplinary approach



Hybrid measures require:

- ✓ **clear institutional capacity** (technical, administrative, etc) to implement all three types of measures (conventional, NWRMs and non-structural).
- ✓ **joint committees/** task forces in order to:
 - provide a smoother permitting.
 - to avoid overlaps and miscommunications
- ✓ **adequate socio-economic conditions**, like blended financing, long-term/multi-year funding stream (not one-off project budget).
- ✓ **stakeholder acceptance**, early involvement and transparent communication

Multidisciplinary approach



Hybrid measures require:

- ☐ **Operational & Maintenance** (O&M) protocols,

Operational rules should include well-defined responsibilities across agencies.

- ☐ **Maintenance** protocols (regular, periodic, post-event),

Insufficient maintenance may lead in performance decline.

*Hybrid system's interface is often a failure prone zone (**unified system**)*

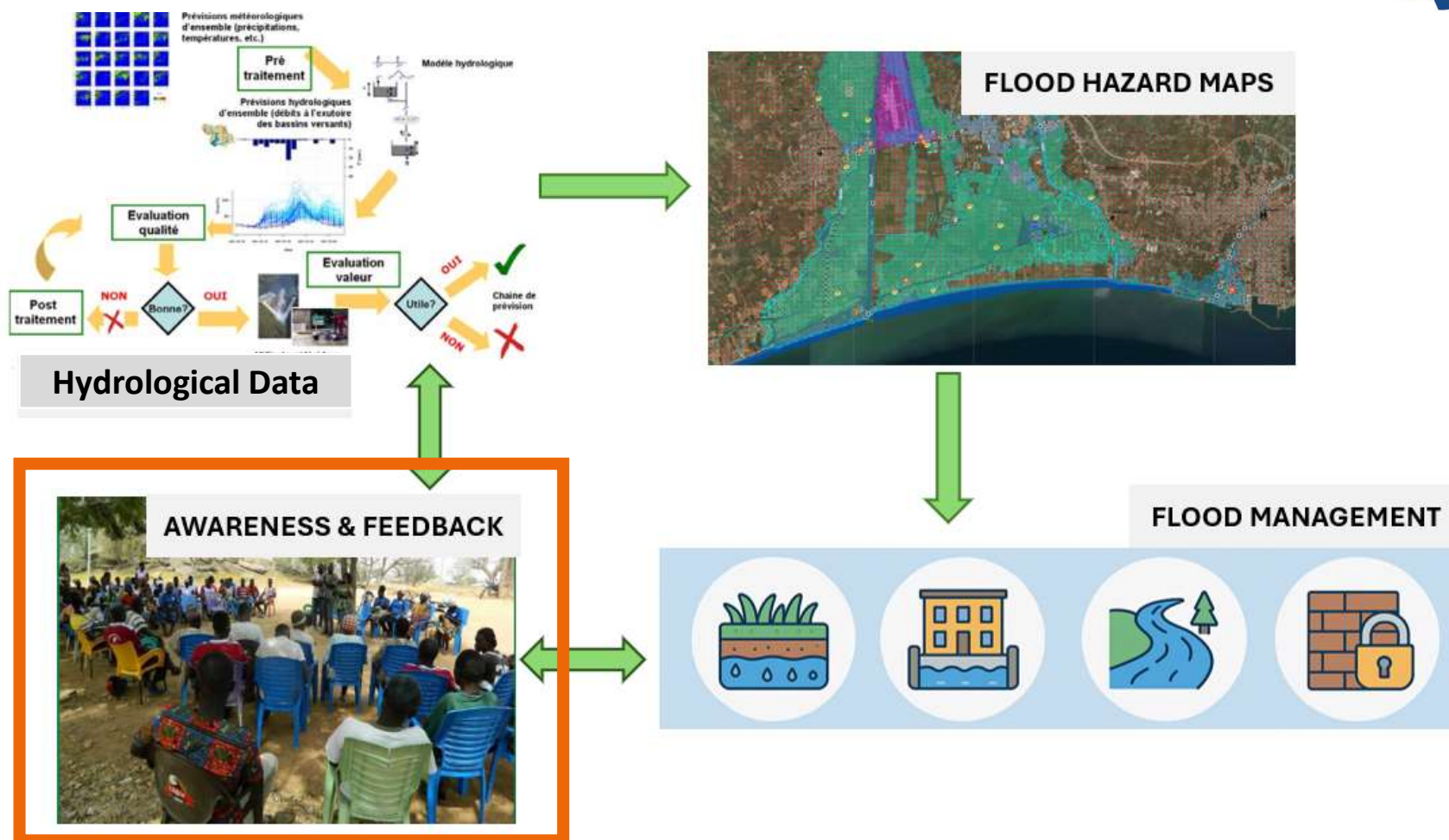
- ☐ **Monitoring** tools

Hybrid interface monitoring is the most critical and includes monitoring both structural assets and NWRMs.

- ☐ **Long-term management.**

Hybrid systems are more robust, but resilience should be evaluated against climate change, urbanisation, infrastructure failure scenarios, etc

Community involvement



Hybrid Measures Synopsis



Combined use of **NWRMs** and **conventional measures** can show indicatively:

- ✓ **10 to 40% reduction in** required **conventional measure capacity** for the same design storm,
- ✓ **20 to 60% attenuation volume reduction,**
- ✓ **0.2 to 0.8 m reduction** levee height,
- ✓ **Pipe diameters reduced** by 1–2 nominal sizes.

Hybrid measures are best suited for rural & peri-urban catchments with space availability for flood storage in areas with lower land acquisition prices.

Flood Management Comparative Summary



Measure Type	Strengths	Weaknesses
Conventional measures	- Predictable hydraulic performance - High reliability for extreme events - Clear design standards & regulation	- High CAPEX & OPEX - Low adaptability to climate change - Environnemental impacts
NWRMs	- High co-benefits - Flood attenuation - Improves ecological status - Flexible to climate variability	- Land-intensive - Limited performance for extreme events - Seasonal variability - Slower permitting in protected areas
Hybrid Measures	- High hydraulic performance - Allows conventional measures downsizing (reduced cost) - Co-benefits - Climate-change robustness - Reduced residual risk	- Higher CAPEX than NWRMs - More complex design & modelling - Interdisciplinary permitting OPEX higher than NWRMs - Requires coordination across agencies and landowners

MEDITERRANEAN : IMPLEMENTATION CHALLENGES



Mediterranean Challenges	Impact on Hybrid Measures
Flash floods, drought–flood cycles, sediment loads	Overloading of NBS, high maintenance
Fragmented governance, rigid public works law	Slow permitting, design incompatibility
Hard-to-quantify co-benefits, short funding cycles	Underinvestment, preference for grey
Sparse data, limited modelling tools	High uncertainty in design/performance
Land-use conflicts, perception issues	Low acceptance, limited space

Hybrid Measures



The term “**hybrid**” doesn’t refer only to combination of different engineering measures. Hybrid measures can (should) include:

Engineering measures

(Conventional, NWRMs or Hybrid)

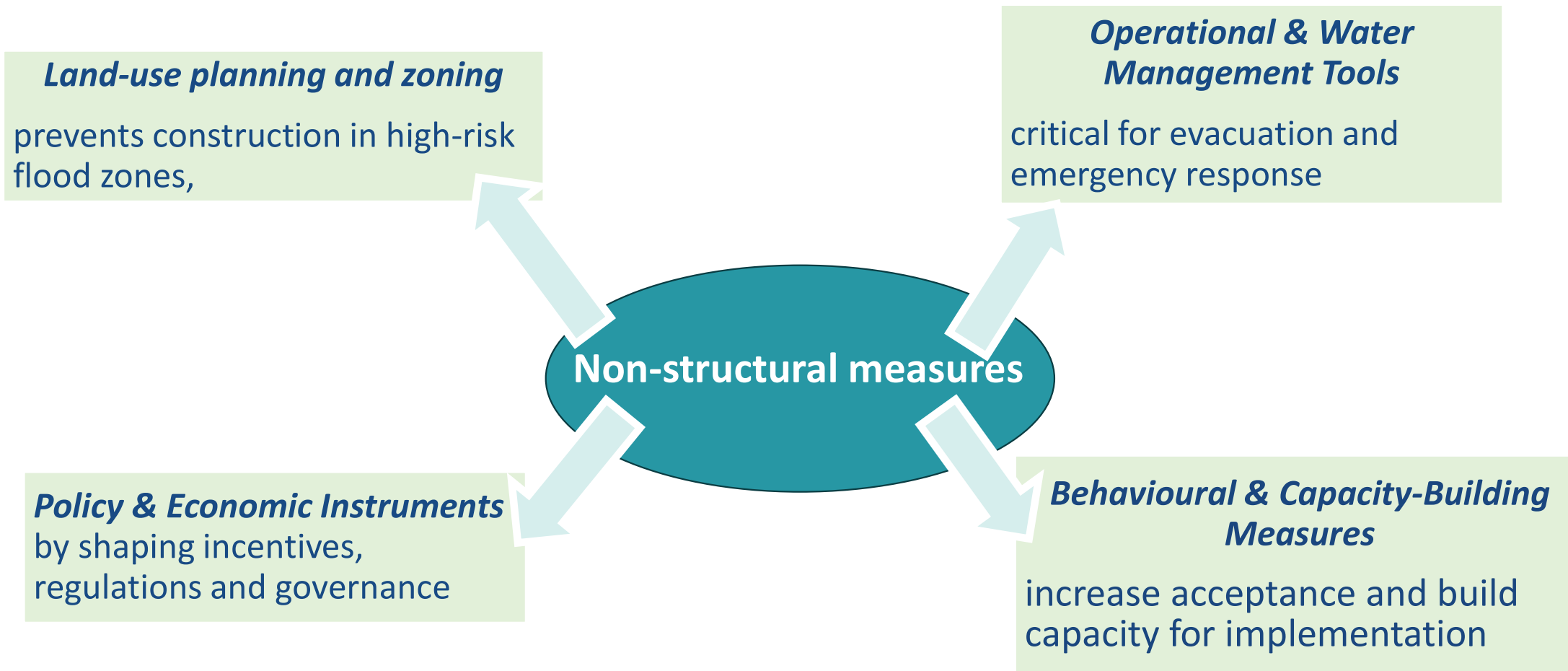


Non-Structural measures

(policies, planning tools, management practices and behavioural or institutional measures)

Non-structural strategies reduce exposure, improve preparedness and manage risk through improvement in land-use planning, strengthening long-term catchment resilience and encouraging behavioural change in communities

Non Structural Measures

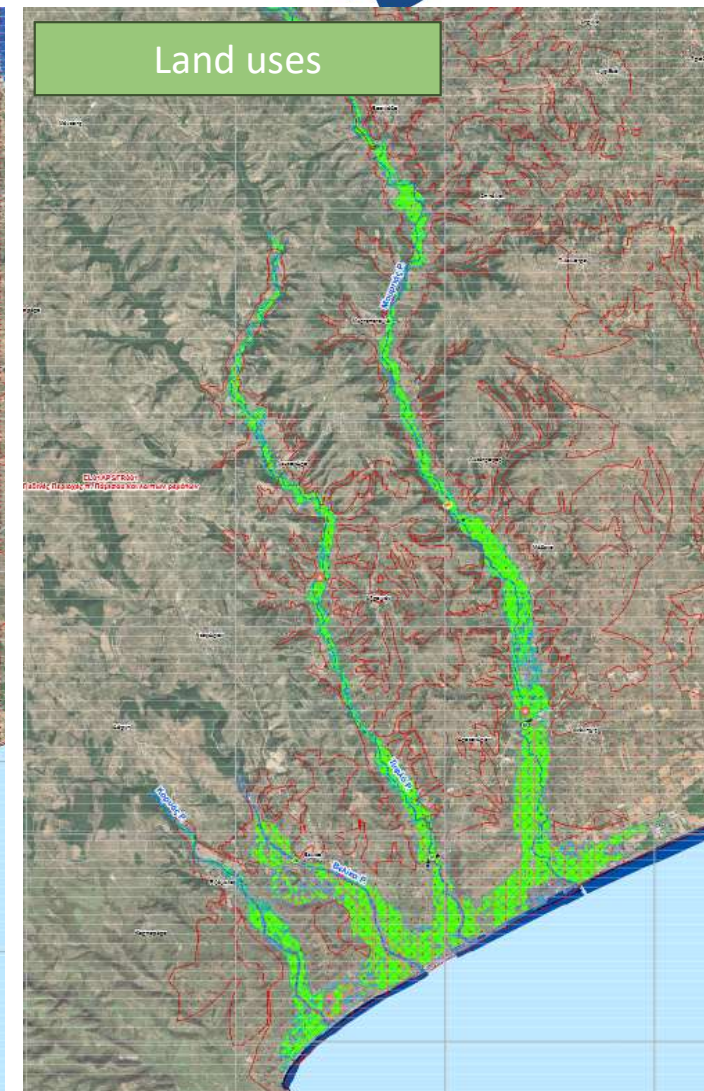
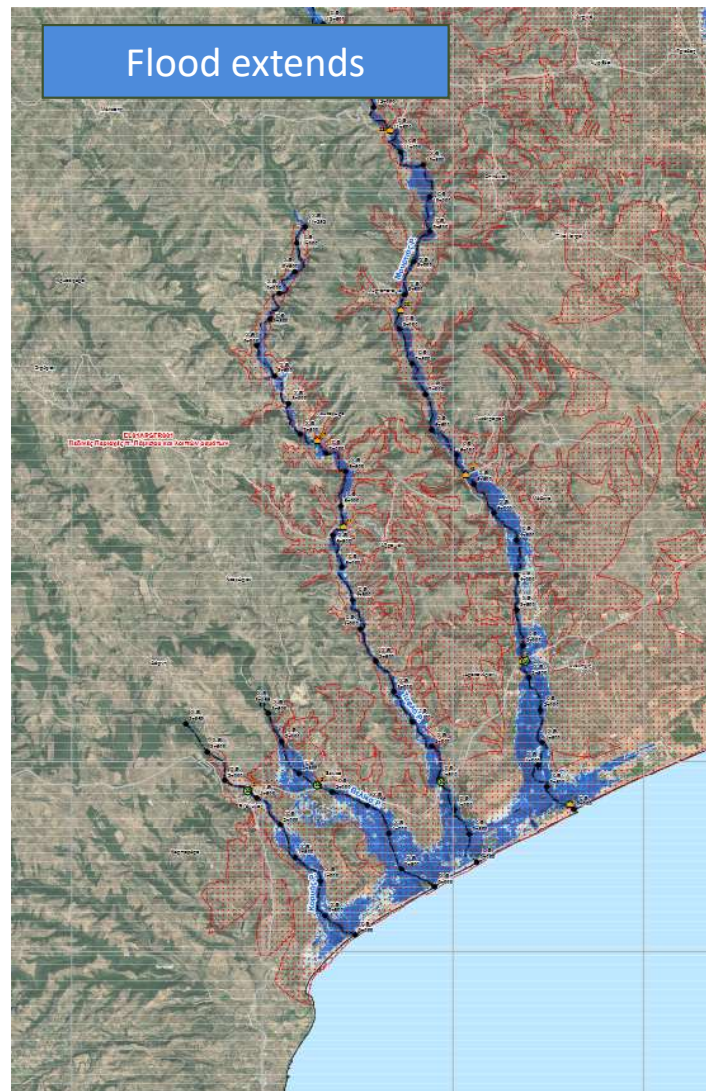


Land-use Planning & Zoning



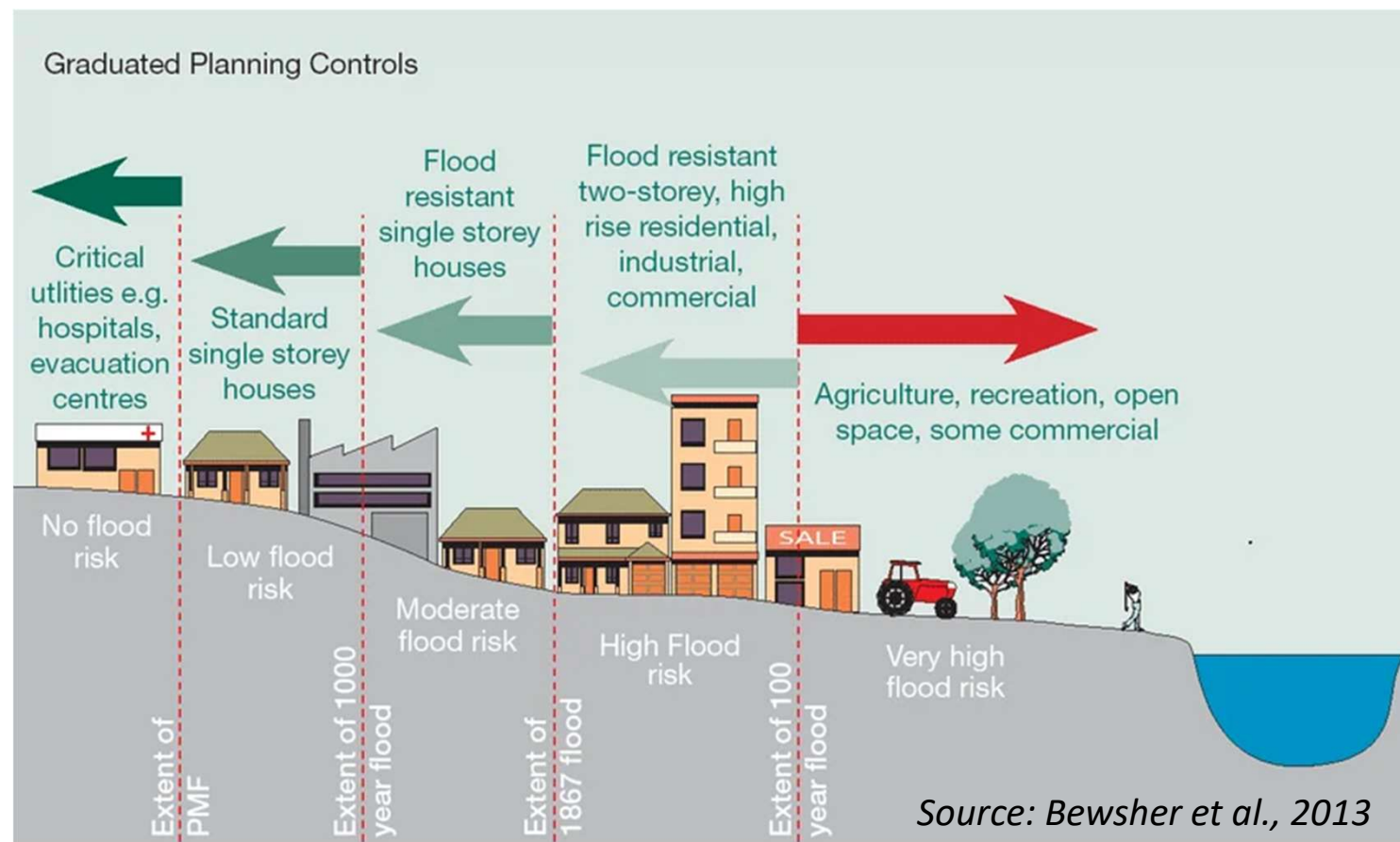
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Land-use planning and zoning
prevents construction in
high-risk flood zones



Land-use Planning & Zoning

Land-use planning and zoning
prevents construction in
high-risk flood zones

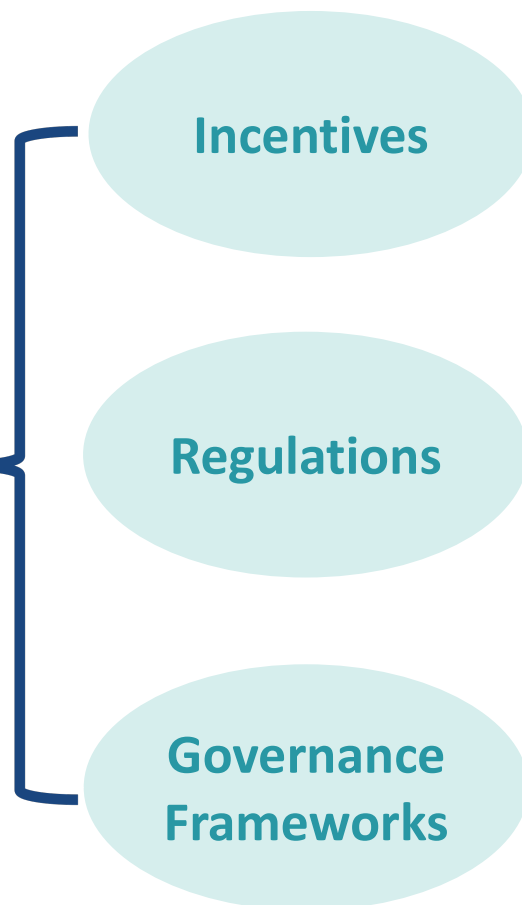


Policy & Economic Instruments



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Policy & Economic Instruments
by shaping incentives,
regulations and governance



Source: Zelenakova et al., 2017

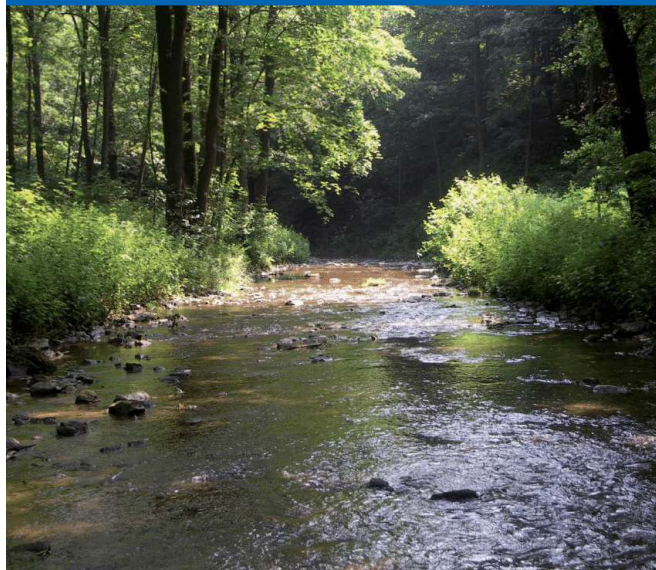
Policy & Economic Instruments



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Water Framework Directive

The way towards healthy waters

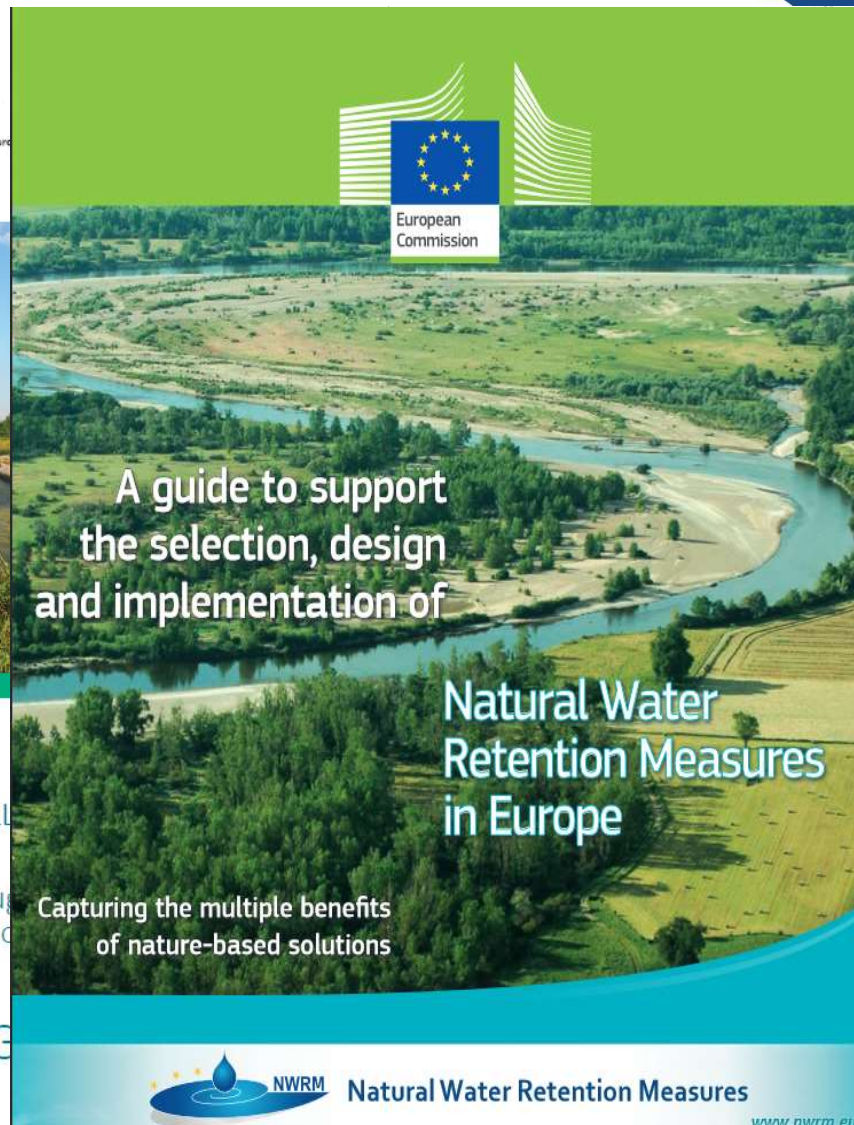


LDK CONSULTANTS S.A.



NATURAL SMALL

combining droug
and bio



Technical Report - 2014 - 082

document on

Retention Measures

ing team of the WFD CIS Working
amme of Measures (WG PoM)



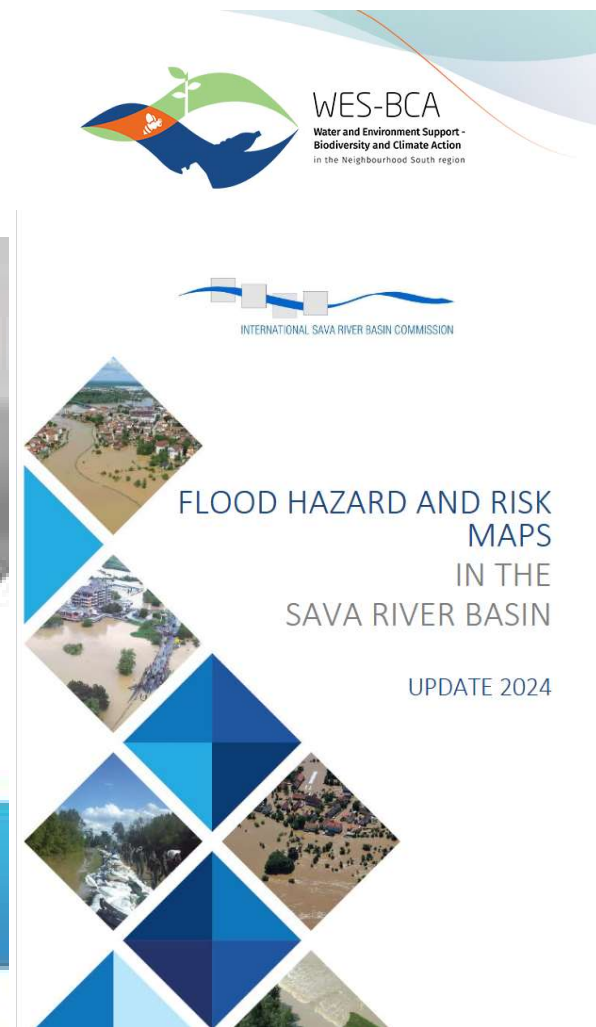
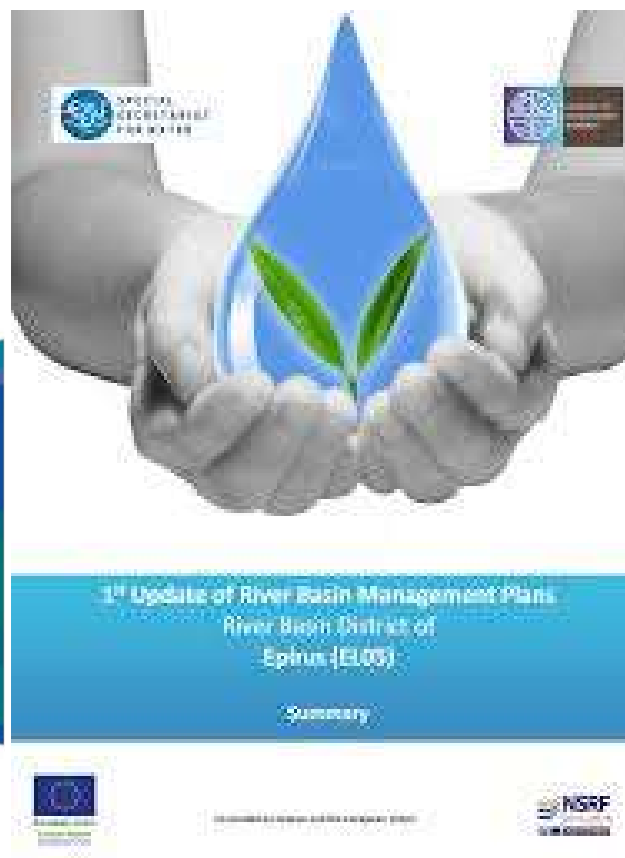
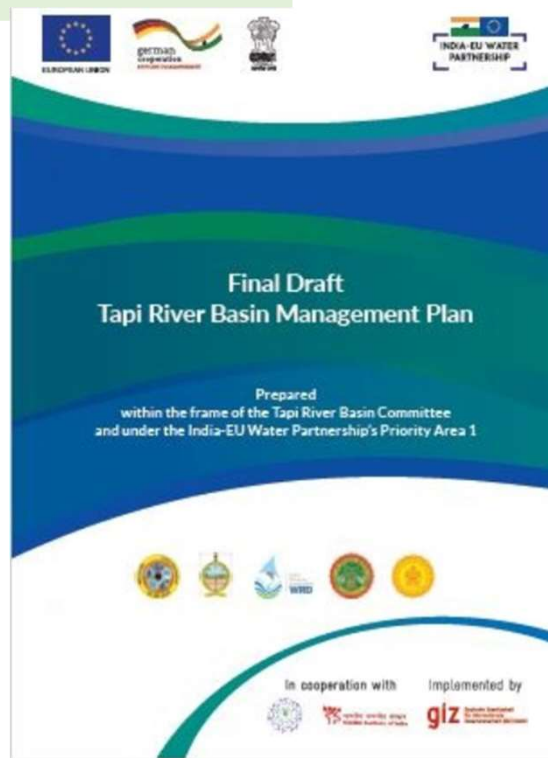
Natural Water Retention Measures

www.nwrm.eu

Operational Management Tools

Operational & Water Management Tools

critical for evacuation and emergency response



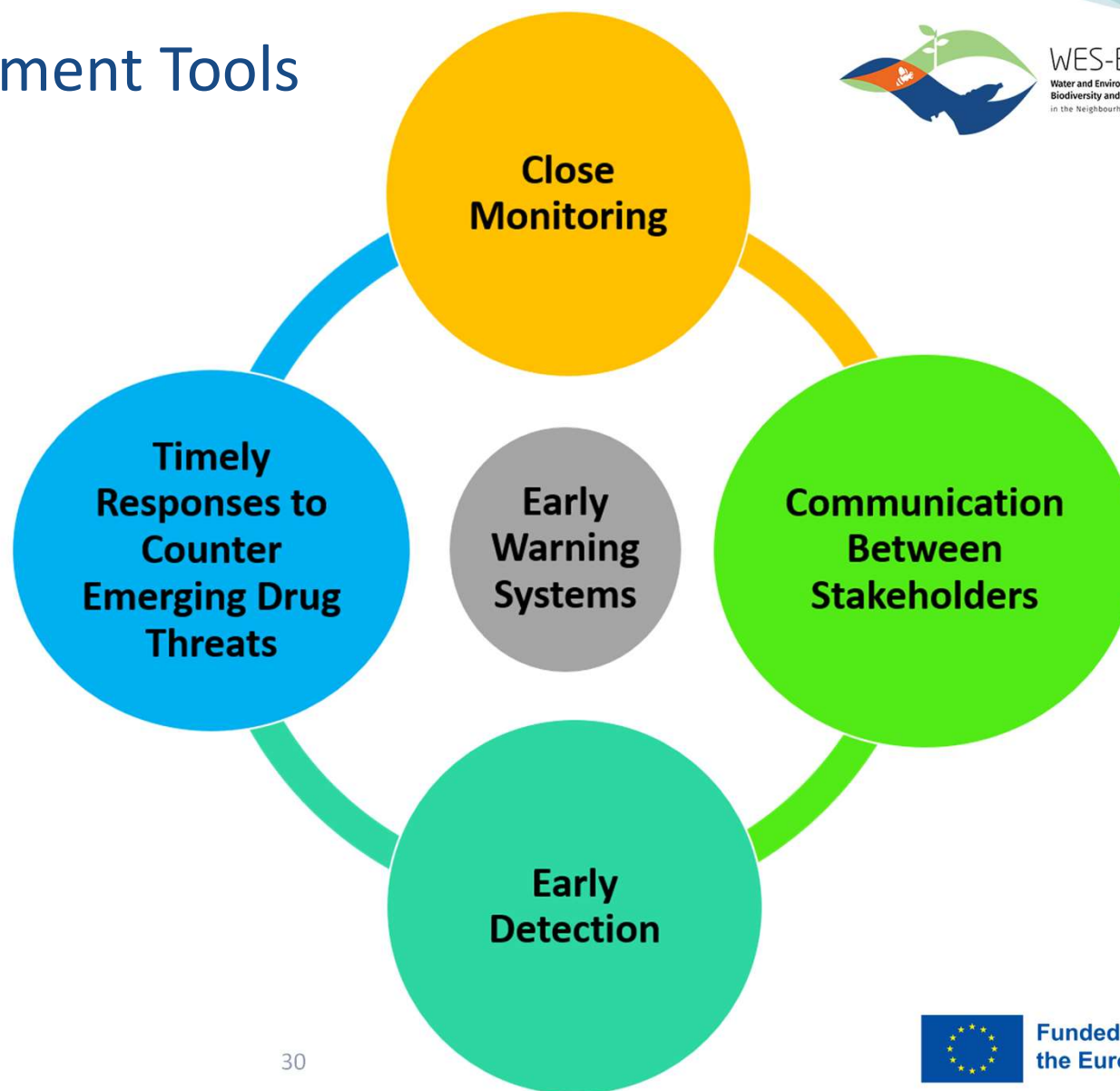
Operational Management Tools



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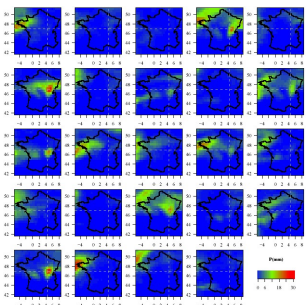
Operational & Water Management Tools

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Operational Management Tools

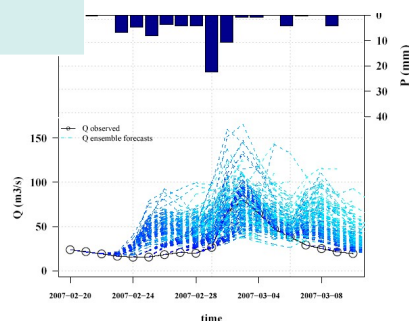
**Meteorological
Forecasts**



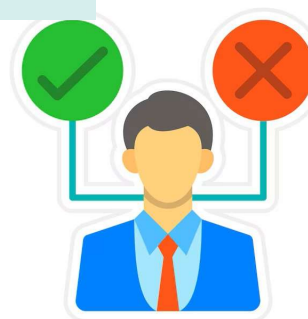
**Hydrological model
(rainfall to runoff)**



**Hydrological
Forecasts**



**Decision
Making**



**Information
Dissemination/
Emergency
Protocols**

**Flood
Emergency Plan**

Before the Flood

- Prepare an emergency kit, secure valuables, and identify evacuation routes.
- Stay informed through weather updates and official channels.

During the Flood

- Follow evacuation orders promptly and avoid flooded areas.
- Turn off utilities if instructed and prioritize personal safety.

After the Flood

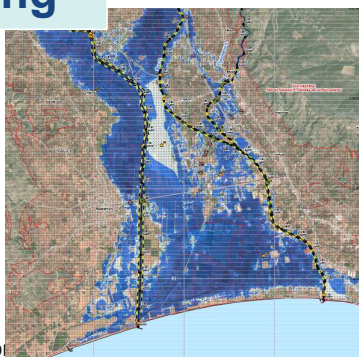
- Return home only when authorities deem it safe.
- Assess damage, contact insurance, and begin cleanup and restoration.

Stay alert. Stay safe.
 inquire@greenshift-mal | 222 555 7777 | Template.net

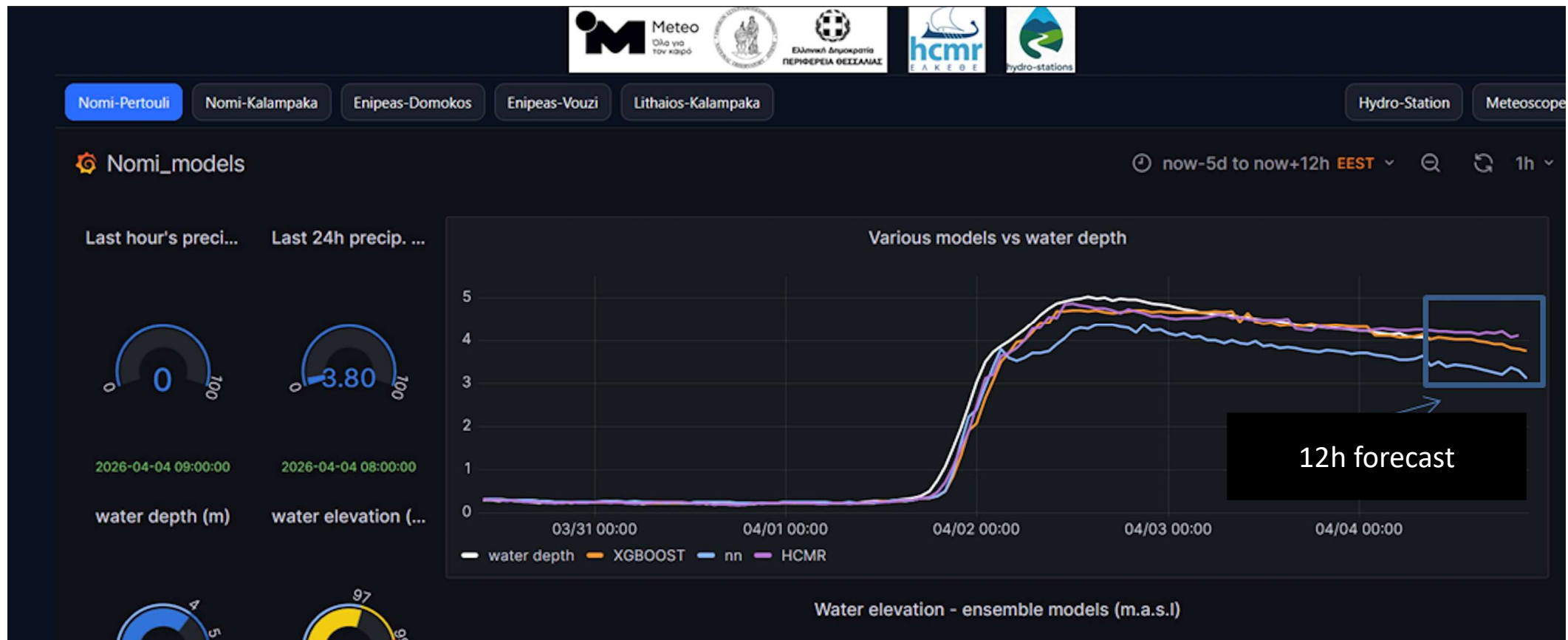
**Operational
applications**



**Hydraulic
Modeling &
FH Mapping**



Example of a AI Flood Forecasting System

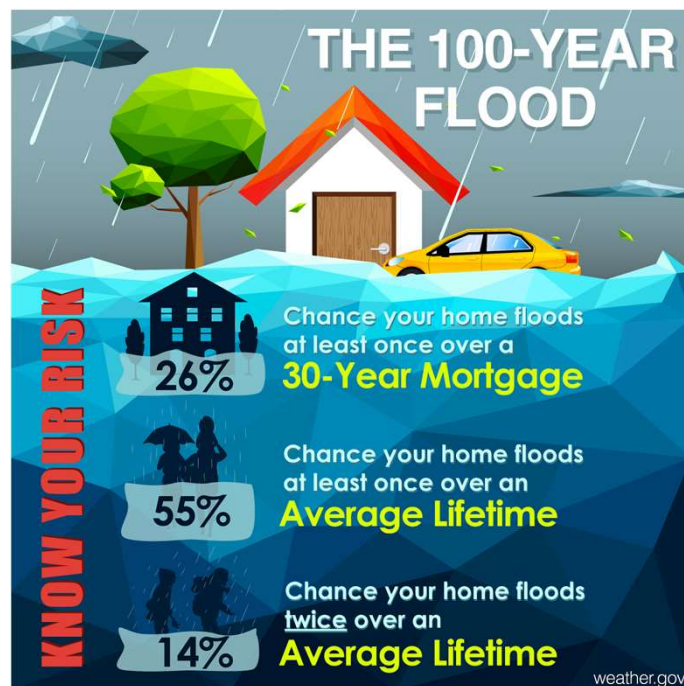


Source: Lagouvardos et al., 2026 and METEO.GR

Behavioural Measures

Behavioural & Capacity-Building Measures

increase acceptance and build capacity for implementation



Source: Tfma flood awareness week



EMERGENCY RESPONSE
ANNOUNCEMENTS OF SELF-PROTECTION MEASURES BY THE HELLENIC FIRE SERVICE

STORMS – FLOODS



During storm – flood:

IF WE ARE IN A BUILDING / HOUSE



Move from basements and go to higher place



If water enters the house, immediately turn off the main power supply



Help disabled people, do not forget pets

IF WE ARE OUTDOORS



Do not move and seek a safe, high place



Never cross rushing water on foot or in a car



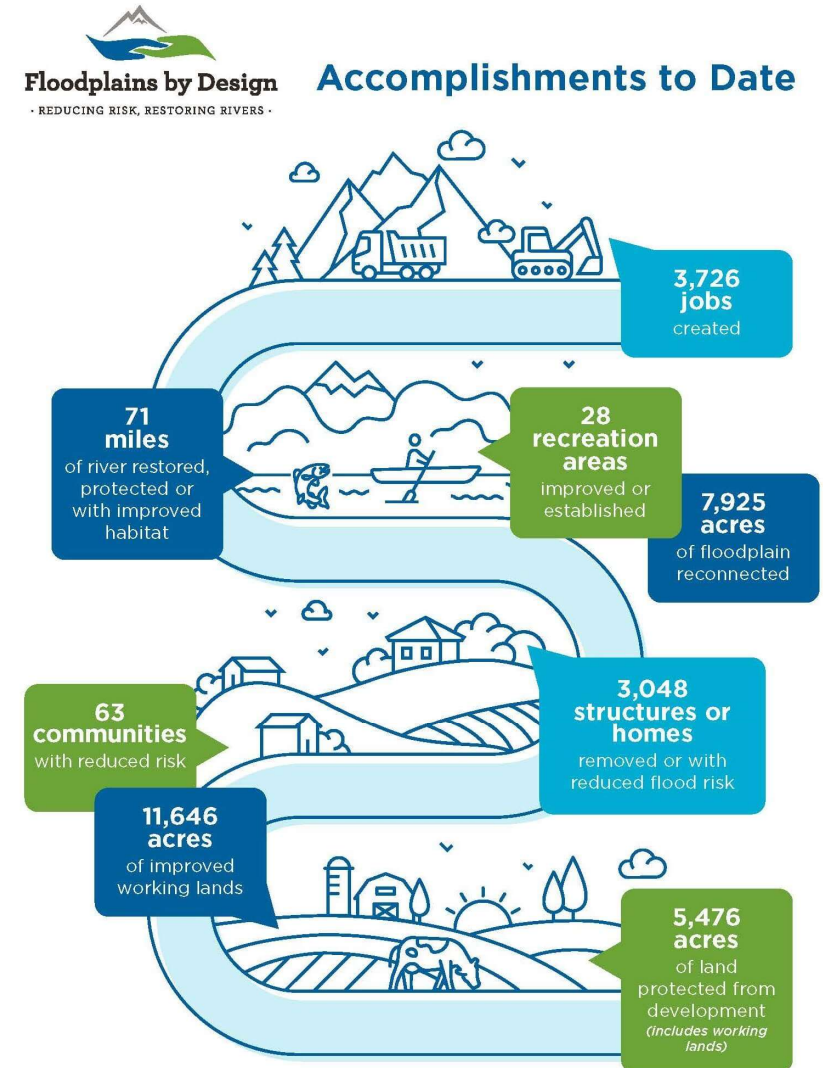
We stay away from power lines

Announcements of self-protection measures by the Hellenic Fire Service at the beginning of Daniel on 5 September. Source: <https://twitter.com/pyrosvestiki/status/1699009586085200268>

Behavioural Measures

Behavioural & Capacity-Building Measures

increase acceptance and build capacity for implementation

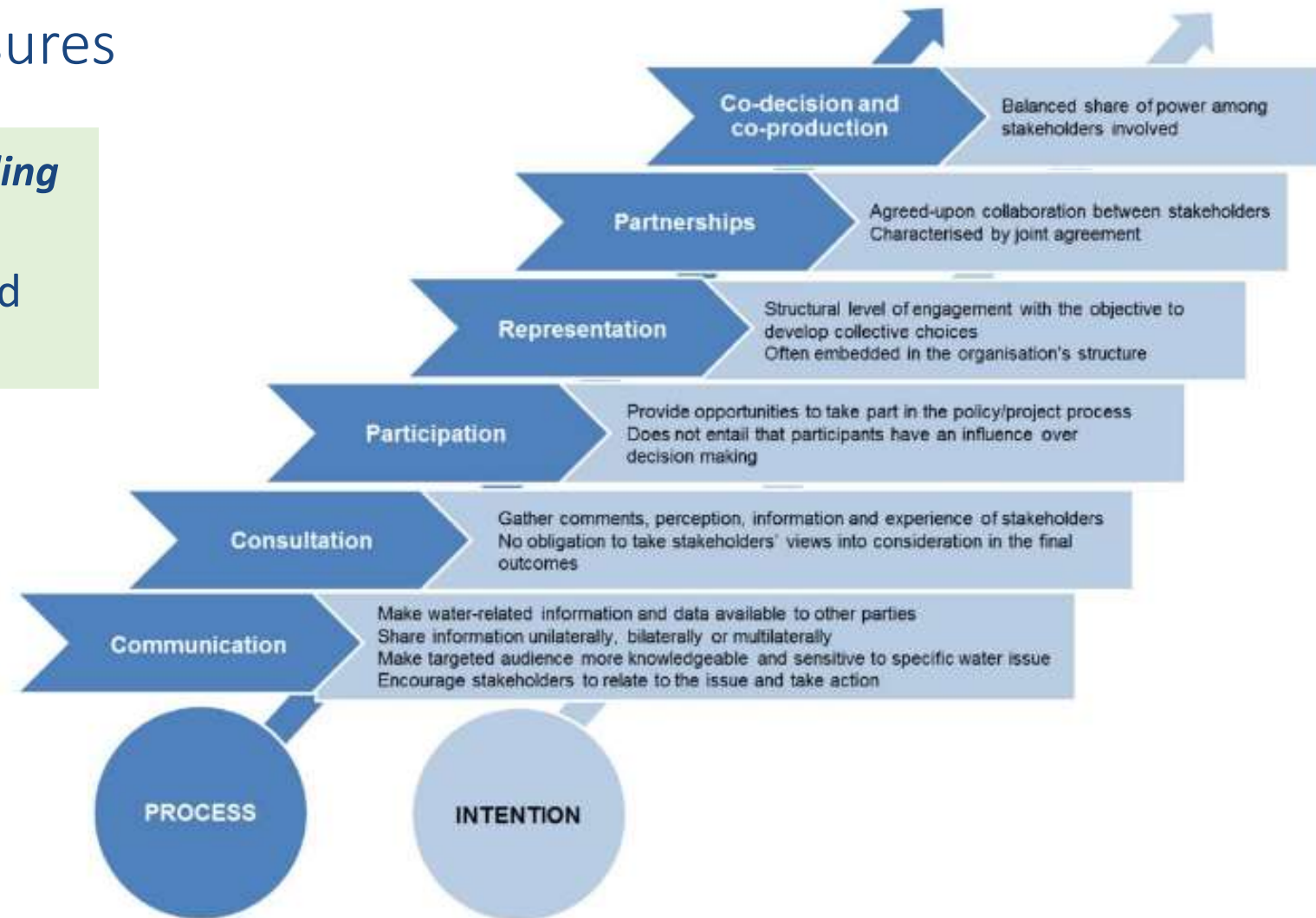


Source: Floodplains by Design Selected Cumulative Grant-Funded Outcomes, 2013-2023

Behavioural Measures

Behavioural & Capacity-Building Measures

increase acceptance and build capacity for implementation



OECD Typology of level of stakeholder engagement

Behavioural Measures – An Example

“Water for the City” program



Stakeholders engagement (source: www.gwp.org)

More than 6000 students trained!



Water for the City program

36 (source: www.gwp.org)

Non Structural Measures Benefits

Non-structural measures provide indirectly significant benefits via:

- ☐ the **management of exposure** through land-use and spatial planning,
- ☐ the **preparedness improvement** and **response planning** through early-warning systems, emergency plans, evacuation protocols and public awareness campaigns,
- ☐ an **effective governance** and **agency coordination**,
- ☐ the establishment of **specialized frameworks**,
- ☐ **financial incentives** (or disincentives) for sustainable land management.

*Non-structural measures are **not** a “stand alone” flood management approach, but complementary to both NWRMs and conventional measures.*

Their effectiveness lies in setting the groundwork for all other measures.

Hybrid Schemes Examples

	Grey Infrastructure	NWRM & Non Structural	Justification
Hybrid Scheme 1: Cities and flash-flood-prone towns	Protect dense urban areas with high asset value (levees, floodwalls, pumping stations)	Urban NWRMs & Non-Structural Measures	Grey infrastructure protects critical assets Green reduces load Green roofs, permeable pavements, swales reduce stormwater entering the system, reduce overload Zoning & early warning systems reduces exposure

Hybrid Schemes Examples

	Grey Infrastructure	NWRM & Non Structural	Justification
Hybrid Scheme 2: Large river basins, floodplain systems, upstream mountainous catchments	Reduce downstream flood peaks (dams, retention basins)	Wetland & Forestry NWRMs & Non-Structural Measures	Wetlands store water and slow hydrographs Forests increase infiltration, stabilize slopes and reduce sediment production Grey infrastructure handle residual peaks

Hybrid Schemes Examples

	Grey Infrastructure	NWRM & Non Structural	Justification
Hybrid Scheme 3: Hydrological basins with strong seasonal variability	Mitigate drought while managing flood risk (reservoirs, etc)	Agricultural & Forestry & Wetland NWRMs & Non-Structural Measures	Soil moisture retention, forest shading and wetland increase climate resilience Grey infrastructure provides backup supply



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Thank you for your attention!