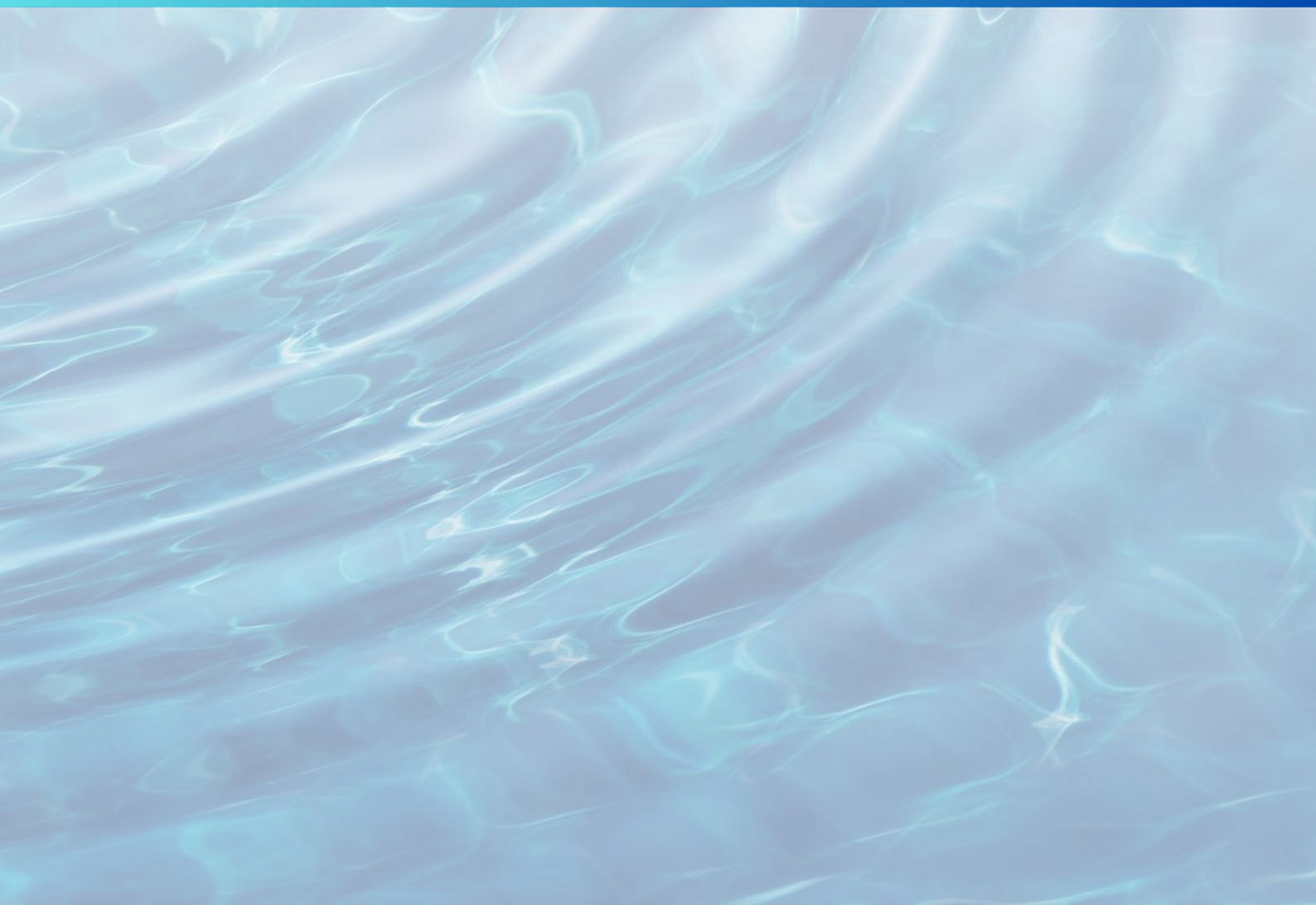




NINFA Policy Brief

Strengthening European Adaptive Groundwater Management



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NINFA Policy Brief

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Introduction

NINFA (Taking action to prevent and mitigate pollution of groundwater bodies) is a Horizon Europe project advancing **integrated groundwater protection and management**. It combines **modelling, monitoring, sensing, treatment technologies, risk assessment and decision-support tools** to address pollution and water pressures. Its **Knowledge Observatory** connects scientific evidence, policy needs and practical resources, **supporting adaptive, sustainable groundwater management** across five implementation domains:

Monitoring, Data
and System
Knowledge

Groundwater
Governance and
Sustainable Resource
Management

Groundwater Quality
Protection and
Pollution Prevention

Climate Adaptation
and Aquifer
Resilience

Circular Water
Management and
Resource Recovery

The NINFA integrated approach highlights that effective groundwater protection depends on connecting monitoring and hydrogeological understanding with risk assessment, treatment and mitigation, and decision-making. Policy frameworks should enable this integration through interoperable data systems, clear institutional responsibilities, adaptive governance and proportionate regulatory safeguards.

NINFA Policy Brief

Strengthening European Adaptive Groundwater Management

Policy recommendations

1. Connect, monitoring, data, models and decisions

Groundwater information is still divided among quantity, quality, climate, abstraction, ecosystem and land-use programmes. More observations will not improve decisions unless data are **comparable, quality controlled** and interpreted through a defensible **hydrogeological conceptual model**.

Key actions: Design monitoring around management questions and aquifer dynamics. Combine periodic sampling with sensors, telemetry, Earth Observation, tracers and models where they add decision value. Apply common vocabularies, metadata and exchange standards, including FAIR principles and interoperable services. Preserve original data, document transformations and use automated quality control transparently.

Expected improvements: Integrated monitoring can support early warning, trend assessment, cumulative-pressure analysis and scenario testing across institutional and national boundaries.

Implementation barriers: Uneven network coverage, legacy datasets, incompatible methods, restricted access, unclear ownership, short project funding and limited hydrogeological and data-management capacity.



2. Make groundwater governance adaptive and aquifer-based

Fixed licences and administrative boundaries often fail to reflect changing recharge, cumulative abstraction, groundwater and surface-water connections, or impacts on ecosystems. Governance should manage the **aquifer response and agreed environmental and social objectives**, rather than individual permits in isolation.

Key actions: Assess availability at aquifer scale and improve abstraction registration, metering and reporting. Introduce staged licences and tiered triggers linked to groundwater levels, rates of decline, spring or baseflow conditions, salinity and recovery. Define actions, review periods, responsibilities and appeal procedures in advance. Use participatory scenarios to make trade-offs and uncertainty visible.

Expected improvements: Management can respond earlier to drought and depletion while giving users clearer expectations and protecting essential uses and environmental functions.

Implementation barriers: Incomplete abstraction data, uncertain thresholds and causality, legal expectations attached to existing rights, enforcement limits, institutional fragmentation and unequal capacity to absorb restrictions.

NINFA Policy Brief

Strengthening European Adaptive Groundwater Management

3. Prioritize prevention and risk-based pollution control

Groundwater pollution is often **detected late and can persist for decades**. Policies centered on threshold exceedance and treatment at abstraction points do not adequately address **diffuse sources, legacy contamination, emerging contaminants or salinization** caused by disturbed hydraulic conditions.

Key actions: Apply source to pathway to receptor assessment across water, agriculture, chemicals, waste and land-use policy. Protect vulnerable recharge and capture zones, use sentinel monitoring and link abnormal signals to predefined investigation and response. Target nitrate and pesticide measures using leaching risk, travel time and receptor sensitivity. Use watch lists, group-based approaches and precautionary source control for persistent and mobile substances.

Expected improvements: Risk-based targeting can reduce contaminant inputs, improve accountability and direct monitoring and enforcement to locations where damage would be most consequential.

Implementation barriers: Diffuse and historical pollution sources, long groundwater response times, uncertain source attribution, analytical capabilities that may advance faster than toxicological assessment and regulation, and fragmented responsibilities across policy sectors.

4. Integrate aquifer recharge and storage into climate adaptation

Aquifers can **buffer seasonal variability and multi-year drought**, but this function depends on recharge, recoverable storage and groundwater discharge to rivers, springs and ecosystems. Climate adaptation should therefore **protect natural recharge and aquifer recovery** while testing measures against several plausible climate and demand futures.

Key actions: Combine climate, land-surface and groundwater observations to assess recharge using multiple methods. Protect infiltration areas and connect abstraction rules to indicators of aquifer condition and recovery. Apply Managed Aquifer Recharge and recharge-oriented Nature-based Solutions only after site suitability, source-water quality, travel time, clogging, ecological effects and operating responsibilities have been assessed. Define performance indicators before operation and expand schemes in stages.

Expected improvement: Groundwater storage can provide a lower-evaporation drought buffer and support ecosystem functions when recharge measures are combined with demand management and sustainable allocation.

Implementation barriers: Uncertain recharge projections, insufficient monitoring duration, scale mismatch, unreliable future source water, water-quality and clogging risks, unclear recovery rights and liability, and the risk that additional recharge simply enables additional pumping.

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Strengthening European Adaptive Groundwater Management

5. Link circular water use to aquifer protection

Water reuse and resource recovery can **reduce freshwater pressure**, but reuse is beneficial only when it replaces abstraction **without transferring nutrients, salts, pathogens, persistent chemicals** or treatment residuals to soils and groundwater. Short demonstrations may miss impacts that appear after **long subsurface travel times**.

Key actions: Design treatment backwards from the intended use and receiving environment. Combine source control, fit-for-purpose multi-barrier treatment, operational thresholds and contaminant-specific monitoring. Where reclaimed water may reach groundwater, require a hydrogeological conceptual model, cumulative mass-loading assessment, monitoring across soil, vadose zone and aquifer, and responsibilities that extend over relevant travel times. Report technology readiness, energy use, residuals and product quality for recovered resources.

Expected improvements: Clear risk-based rules can support safe freshwater substitution, nutrient and energy recovery, and investment in treatment systems suited to local conditions.

Implementation barriers: Regulatory fragmentation among reuse applications, uncertain emerging-contaminant risks, salinity and concentrate management, infrastructure mismatch, variable technology maturity and markets, long-term liability and public trust.



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NINFA Policy Brief

Strengthening European Adaptive Groundwater Management

CROSS-CUTTING IMPLEMENTATION PRINCIPLES

These cross-cutting principles define the conditions needed to implement the five policy recommendations consistently across different hydrogeological, regulatory and institutional contexts. They aim to ensure transparency, accountability, continuity throughout the process, from evidence generation to implementation and periodic review.

1. Ensure that data, analytical methods, assumptions and uncertainties remain traceable from monitoring to management decisions.
2. Define decision triggers, responsibilities, review procedures and corrective actions before relevant groundwater quality thresholds are exceeded or deterioration occurs.
3. Maintain continuity of monitoring, data stewardship and institutional responsibilities beyond individual projects and short-term funding cycles.
4. Assess the distributional effects of management decisions and involve groundwater users, affected communities and relevant sectoral authorities in decisions that may alter access to water, costs or exposure to risk.

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