POLICY BRIEF 3

MAR2PROTECT

Policy recommendations for the sound integration of Managed Aquifer Recharge in groundwater management

Key message

Groundwater resilience requires managing water quantity and quality together. Circularity and reclaimed water reuse contribute to groundwater resilience, but only when paired with strong groundwater protection requirements, risk-based monitoring, and effective institutional coordination. Managed Aquifer Recharge (MAR) is increasingly used as a water management strategy to preserve and augment groundwater. MAR should therefore be explicitly integrated into the EU water policy framework with particular attention to Pollutants of Emerging Concern (PECs) and digital monitoring and control tools.

Highlights

- Groundwater resilience requires managing water quantity and quality.
- Circularity must not come at the expense of groundwater protection. There is a strong need to harmonize the list of contaminants and PECS, as well as their thresholds across the EU water policy framework.
- MAR must be integrated into the Groundwater Directive (GWD), and its implementation harmonized across Member States.
- Given the complex nature PECs, managing the relationship between groundwater scarcity and groundwater quality can benefit from adopting new digital technologies.

From groundwater protection to groundwater resilience

Rapidly increasing water demand, driven by population growth and climate change, has strained water supplies and depleted groundwater reserves. 75% of the EU's overall water supply and about 65% of drinking water come from groundwater; therefore, its depletion is a worrying issue, as it is also the leading cause of **water scarcity** (Alam et al., 2021), with many basins and aquifers already passing depletion limits (Madani, 2026). This raises concerns for policymakers aiming to strenght groundwater resilience and control pollution.

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In the European Union, the **2025 EU Water Resilience Strategy** aligns with the **EU Green Deal** in promoting the principles of **circularity and resilience**.

Groundwater protection should not be reduced to mere pollution control.

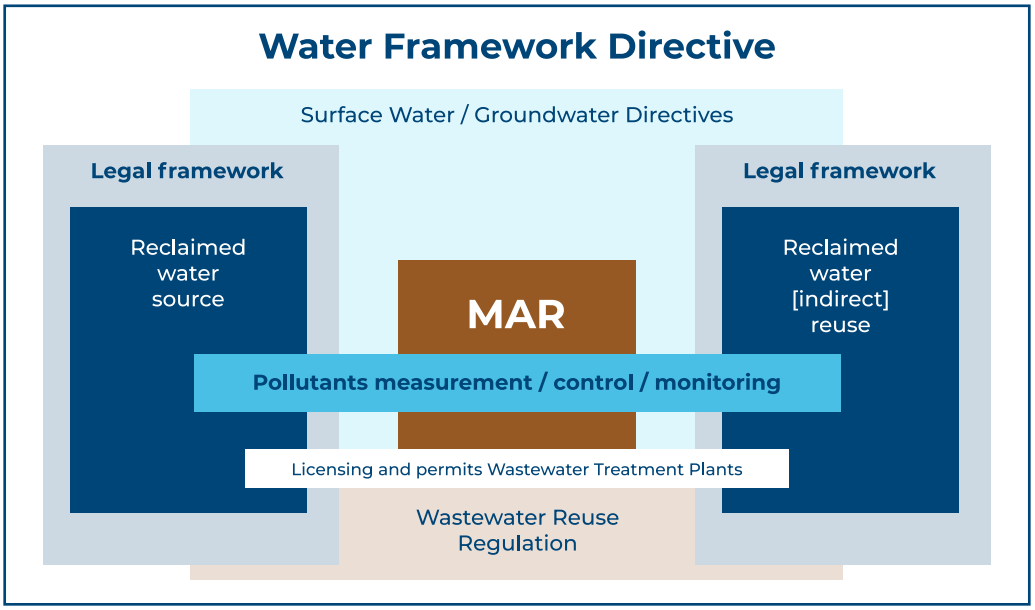
Depletion and contamination are mutually reinforcing pressures: excessive abstraction reduces aquifer resilience and natural recharge, while contamination further reduces usable groundwater. **Groundwater protection is becoming less about protecting a static resource and more about actively managing groundwater, particularly aquifers, as a dynamic socio-environmental system.** One technical solution to address groundwater scarcity and to protect and enhance groundwater quantity is MAR. MAR is increasingly used as a water management strategy to preserve and augment groundwater.

Groundwater protection and reclaimed water reuse should not be treated as separate policy domains.

As climate and global changes increase pressure on groundwater, **reclaimed water and MAR can become important components of groundwater resilience.** However, this requires a water regulatory framework that ensures that the quality of water entering the aquifer is compatible with long-term aquifer protection, particularly with respect to **PECs**, which include **PFAS, pharmaceuticals, microplastics,** and other persistent micropollutants. Therefore, the underlying challenge in achieving sustainable water resilience lies in balancing groundwater-body augmentation and water quality. A controversial solution is **reusing treated wastewater** (also known as ***reclaimed water***) as source water to recharge aquifers. This requires a careful balance between reusing reclaimed water as a source water for MAR and reusing it after its extraction. **It raises the critical issue of controlling, treating, and monitoring PECs across the water-source and water-reuse domains.**

This highlights the need to shift from preventing contamination and controlling groundwater abstraction to an **integrated groundwater resilience pathway** that includes preventing pollution and controlling abstraction, restoring recharge, monitoring PECs, managing risks from reclaimed water reuse, and coordinating institutions. **To pursue this effort safely requires recasting directives in the EU water policy framework to align pollutants and their thresholds with the current health status of EU waters**, as outlined in the specific recommendations below.

Conceptual Framing of EU Water Policies Influencing MAR



Source: Vallejo et al. (2026).

Policy recommendations

Based on the above, MAR2PROTECT identifies five mutually reinforcing priorities: (1) integrate MAR into groundwater policy; (2) harmonize implementation while retaining site-specific risk assessment; (3) strengthen digital monitoring and data infrastructure; (4) align pollutant lists and thresholds of PECs; (5) strengthen groundwater and soil pollution prevention, including Nature-based Solutions (NbS) and sustainable agriculture, for each of which it offers specific recommendations.

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Water Resilience

Key issues Groundwater depletion and contamination

Why it matters?

- → Current MAR schemes operate at the intersection of diverse EU water policies.
- → MAR lacks a clear legal framework, which complicates implementation.

Lessons learned/reflection

- → MAR should be treated as part of groundwater protection, not simply as a water supply technology.
- → Reclaimed water creates both an opportunity and a new groundwater protection challenge.

EU-level Policy Recommendation

Explicitly integrate and strengthen MAR practices in the GWD and related EU water policy framework, particularly regarding the reuse of reclaimed water as source water for aquifer recharge.

Implementation focus

MAR can serve simultaneously as a groundwater-management and groundwater-protection instrument. Thus, MAR should be understood as a tool to restore, protect, and increase the resilience of groundwater systems.

EU-level Policy Recommendation

Harmonize MAR implementation requirements and processes across EU Member States, particularly regarding the reuse of reclaimed water as source water, while retaining site-specific risk assessment.

Implementation focus

Legislation alone is not sufficient. Implementation depends on coordination among national governments, river-basin authorities, regional governments, municipalities, water boards, wastewater operators, and environmental agencies. A shift is needed from fixed pollutant lists and uniform standards to site-specific monitoring, risk assessment, and adaptive management.

Digital monitoring and control across EU waters

Key issues Monitoring and data gaps

Why it matters?

- → Currently, PEC monitoring is often project-based rather than systemic.
- → There is no centralized, publicly available database to harmonize findings on how PECs behave in groundwater, for example, during recharge.

Lessons learned/reflection

Effective groundwater protection requires institutional coordination, a risk-based and adaptive approach, and a standardized permitting system.

EU-level Policy Recommendation

- → Strengthened guidelines for a digital and integrated monitoring approach for groundwater quality regarding PECs and their inclusion in the upcoming River Basin Management Plans (RBMPs).
- → A coherent and interoperable digital risk monitoring strategy and infrastructure to monitor groundwater pollutants in a harmonized way across Member States.

Implementation focus

Water legislation should include prevention, control, and monitoring based on site risk analysis and assessment. At the local level, advanced monitoring and modeling are needed; modeling can assess climate-change impacts and help design MAR systems using different water sources.

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Groundwater protection

Key issues Diverging pollutant lists, particularly PECs

Why it matters?

A significant discrepancy exists between the EU "pollutant lists" and the lists used in national or sub-national policies. This lack of harmonization makes it difficult for Member States to transpose EU mandates effectively.

Lessons learned/reflection

Protection requires a shift from conventional pollutants to emerging contaminants.

EU-level Policy Recommendation

- → Establish integrated risk and monitoring thresholds for emerging pollutants (particularly for reclaimed water reuse), as in the Urban Wastewater Treatment Directive (UWWTD) and Drinking Water Directive (DWD).
- → Support restrictions on the use of persistent, mobile, and toxic (PMT) substances, including PFAS.
- → Additions to the lists of pollutants in the Groundwater Watch List in connection with microbiological and human viruses based on significant EU project detections.

Implementation focus

Reclaimed water reuse can help restore depleted aquifers, but it can also introduce micropollutants into groundwater if insufficiently treated. Hence, promoting circularity and water reuse must go hand in hand with strong source-water quality requirements, advanced treatment, monitoring, and risk assessment when reclaimed water enters groundwater. Therefore, the EU water policy framework needs updating to incorporate PECs.

Groundwater protection

Key issues Groundwater and soil pollution

Why it matters?

Once groundwater and soil are polluted, it is more complex and costly to restore them to a healthy status. Agriculture is one of the main sources of groundwater pollution and therefore requires special attention.

Lessons learned/reflection

Groundwater protection should focus on prevention at the source, not only end-of-pipe treatment.

EU-level Policy Recommendation

- → Support NbS as instruments to mitigate groundwater pollution.
- → Support sustainable agricultural practices and strengthen targeted monitoring of pesticides in groundwater.

Implementation focus

Support NbS as complementary instruments to mitigate groundwater pollution, alongside MAR, advanced treatment, and monitoring. Implementing stronger water-quality requirements will also require technological innovation and appropriate financing, including private-sector engagement.

Source: Vallejo et al. (2026).

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Implementation pathway for these recommendations

- Move from a fragmented regulatory approach to an integrated groundwater resilience pathway covering pollution prevention, abstraction control, recharge restoration, monitoring, reclaimed-water risk management, and institutional coordination.
- Clarify responsibilities and coordination mechanisms among national governments, river-basin authorities, regional governments, municipalities, water boards, wastewater operators, and environmental agencies.
- Complement traditional pollutant lists and uniform standards with site-specific risk assessment, monitoring, and adaptive management where reclaimed water is used for aquifer recharge.
- Ensure that implementing strengthened wastewater requirements is accompanied by investment in treatment, monitoring, and digital infrastructure. Encourage new technologies that help meet emerging-pollutant thresholds in financially viable ways.
- Use RBMPs as a strategic vehicle to connect groundwater quantity, quality, monitoring, climate risks, and recharge measures.

Evidence base

This policy brief draws on MAR2PROTECT Deliverable D6.7, and the evidence and references presented therein. It preserves the deliverable's core findings and recommendations while restructuring them for a policy audience.

How to cite

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Project summary

The MAR2PROTECT project (2023-2026) provided an innovative, holistic approach to prevent groundwater contamination from global and climate change impacts by developing innovative MAR technologies and a new generation of MAR management tools. The core of this innovative MAR approach is the M-AI-R-DSS tool, a Decision Support System (DSS) that incorporates technological and societal engagement information using an Artificial Intelligence (AI)-based tool to help monitor and enhance groundwater quantity and quality in real time.

More information at **www.mar2protect.eu**

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