Project deliverables

Deliverable #D3.2

General Governance Framework for MAR agreements

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AGREEMAR

Adaptive agreements on benefits sharing for managed aquifer recharge in the Mediterranean region

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General Governance Framework for MAR agreements

Author(s)

Syrine Ghannem (UPV), Rafael J. Bergillos (UPV), Joaquín Andreu (UPV), Javier Paredes-Arquiola (UPV), Abel Solera (UPV)

Executive summary

Deliverable D3.2 presents a general governance framework to support managed aquifer recharge (MAR) agreements. It provides a fundamental basis, paving the way for the co-creation of committed and responsible agreements that are essential to the effective management of MAR systems. The key objective of this document is to articulate a clear approach to formulating a set of agreements tailored to the nuances of MAR systems. By analyzing the essential elements involved in MAR and its relations, we present a structured approach, guiding actors on how to build agreements that are aligned with sustainability principles. This document does not just propose a theoretical framework; it serves as a practical guide, offering insights into the development of agreements essential to build and maintain sustainable MAR systems.

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Deliverable author(s)	Syrine Ghannem (UPV), Rafael J. Bergillos (UPV), Joaquín Andreu (UPV), Javier Paredes-Arquiola (UPV), Abel Solera (UPV)
Quality assurance	Anika Conrad (adelphi), Anis Chkirbene (INAT), Constantinos F. Panagiotou (ECoE), Teresa E. Leitão (LNEC)
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Abstract

Governance agreements are essential for converting managed aquifer recharge (MAR) solutions into practicable and long-lasting sustainable practices. This deliverable presents the need for strong governance frameworks to effectively manage MAR systems. It considers existing theoretical approaches to MAR governance, highlighting the need for adaptability, public engagement and comprehensive regulations. Based on global experiences, as well as contributions by general stakeholders and regional stakeholders, the deliverable identifies key lessons and highlights the role of regulatory frameworks in achieving sustainable MAR systems. The general governance framework proposed for MAR by the AGREEMAR project integrates technical, social, economic and regulatory aspects. The deliverable details the elements to be considered when drafting agreements for MAR, including preliminary assessment, stakeholder analysis, identification of potential MAR sites, technical assessments, and compliance with standards and regulations. This emphasizes the importance of incorporating various elements, such as the results of feasibility mapping, indicators and operating rules facilitated by decision support systems and modeling tools for integrated and sustainable water resources management, and institutional feasibility. Furthermore, it highlights the importance of clarifying roles and responsibilities, and provides a general methodological framework for water allocation and compensation mechanisms.

Table of contents

List of figures

1. Introduction

Water is a finite and vital renewable resource that requires management strategies to ensure the regeneration of its natural cycle, guaranteeing the maintenance of life on Earth, meeting the increasing demands of a growing global population for water (LeRoy, 1995; Lukenga, 2015; Rogers and Hall, 2003). As the world is dealing with the challenges of water scarcity, there is an urgent need to investigate long-term solutions that go beyond short-term relief (Pereira et al., 2009). Given this, Managed Aquifer Recharge (MAR) stands out as an essential intervention that aims to improve groundwater replenishment using intentional recharge methods. It is not only an enhancement of aquifer recharge, but also a pillar of long-term water sustainability, ensuring the resilience and availability of water resources for future generations (Escalante et al., 2023). A variety of strategies, including surface water manipulation, artificial recharge techniques and infiltration processes, are used in MAR systems to enhance natural aquifer recharge. These methods are essential for replenishing aquifers and preserving the delicate equilibrium of water tables (Dillon et al., 2009; Ringleb et al., 2016; Zhang et al., 2020).

Groundwater resource overuse and polluted aquifers are making governance a more pressing and divisive topic. Although there has been a lot of scholarly research on water conflicts in general, there has not been much done to address groundwater conflicts (Jarvis, 2014). When water shortages and geopolitical tensions collide, cooperative measures are crucial to avert future confrontations and guarantee the sustainable use of available resources.

MAR systems lie at the critical stage of explicit or implicit agreements. Explicit agreement may take the form of a formal agreement, setting out the conditions for the implementation of the MAR system. Implicit agreements, on the other hand, may emerge where implicit approvals by the river basin agencies pave the way for the practical implementation of MAR practices. These agreements become the keystone, ensuring that MAR transcend theoretical discussions and progress toward tangible, sustainable solutions for water recharge.

This governance framework offers the required organization for well-coordinated MAR implementation initiatives. It shows how the effective execution of MAR systems is dependent on a complex interplay of factors. These factors include socio-political considerations, legal frameworks and community engagement in addition to technical aspects of recharge mechanisms (Dillon et al., 2022; Casanova et al., 2016). The intentional establishment of governance agreements emerges as a critical juncture across MAR governance.

The MAR governance framework proposed by the AGREEMAR project explores the multitude of variables influencing the success of MAR, with a particular emphasis on the crucial role played by agreements. This document seeks to provide a thorough understanding of the governance framework's significance in unlocking the full potential of MAR systems, drawing on insights from a diverse range of literature and real-world examples. The scope of MAR governance framework is covered in detail in this deliverable, which incorporates several key elements to ensure its effectiveness. Firstly, it involves a co-creation process with general stakeholders for endorsement and regional stakeholders for approval, fostering inclusivity of the main stakeholders identified in WP1 (Conrad et al., 2022). Additionally, it integrates the results of feasibility mapping obtained in WP2 (see Panagiotou et al., 2022, Martins et al., 2022, Chekirbane et al., 2023), enriching the framework with data-driven insights. Indicators and operating rules, depicted in D1.1 (Ghannem et al., 2023a), are facilitated by decision support system interfaces, modeling tools and soft system methodologies from WP3 and WP4 ensuring a holistic approach to integrate sustainable water resources system management.

This report examines the complex network of variables affecting MAR success, emphasizing the critical role played by agreements. This document attempts to give an in-depth comprehension of the significance of governance framework in achieving the potential of MAR systems, drawing on an array of literature and real-world examples. At the same time, it innovates, contributing to the incorporation of collaborative approaches, to integrate, with the necessary depth and care, increasing involvement of stakeholders, facilitating the co-creation of agreements based on the force of the law and through the force of the will to build a governance that comes close to what is defined as Good Governance. For Grigg (2011), among other aspects, this means a transparent decision-making with fair participation mechanisms, resulting in an equitable and ecologically healthy distribution of resources.

2. Theoretical foundations for MAR governance

2.1. Water Governance for MAR

Water governance can be defined as the spectrum of formal and informal political, institutional and administrative regulations, practices and processes. Within this framework, decisions related to water management are made and implemented. It encompasses the ability of stakeholders to express their interests and ensure that their concerns are considered. It involves holding decision-makers accountable for their roles in the management of water resources (OECD, 2015).

As defined by Dillon et al. (2009), Managed Aquifer Recharge (MAR) is the practice of deliberately recharging aquifers to recover the water at some point in the future and/or for environmental or water quality reasons. It is considered as a multi-purpose water management tool, which incorporates a variety of water sources, recharge techniques and storage management practices.

Integrating MAR into water governance requires a nuanced approach, considering local hydrogeological conditions, land use patterns and socio-economic factors. Such governance frameworks need to address issues such as ownership of recharge infrastructure, allocation of recharged water and potential conflicts of interest. In addition, robust regulatory mechanisms need to be put in place to control and manage MAR activities to ensure their sustainability and prevent unexpected consequences (Zheng et al., 2021; Dillon et al., 2022). The regulatory mechanism needs to be flexible enough to accommodate the possible changes in society, technologies and nature (lifestyle, land use, population fluctuation, new water technologies, climate changes). In addition to the strength of regulatory instruments, it is recommended that, in the context of developing MAR systems, the willingness of stakeholders to build MAR is fomented, as well as the acceptance of the beneficiaries to use recycled water.

2.2. Local Dynamics in MAR Governance

The exploration of local power dynamics in MAR reveals a complex interplay of interests and influences that shape decision-making in aquifer management. Local power structures, including governmental bodies, community leaders and influential stakeholders, play a pivotal role in determining the direction of MAR initiatives. Understanding these dynamics is crucial for developing effective and inclusive water management strategies that address the diverse needs and concerns of the local population (Casanova et al., 2016; Jarvis, 2014; Dillon et al., 2022). To this end, the constellation analysis (CA) methodology (Rodorff et al., 2015) is a very useful tool for organizing the elements involved and understanding the relationships between them and the actors involved. This tool can be used not only locally but in all scales of governance and in a diversity of cultural realities.

The adaptation of theories of cooperation and conflict resolution to local contexts is fundamental, emphasizing collaboration among local actors. Practical approaches from prior MAR cases provide valuable insights, offering a pragmatic foundation for MAR governance. An alternative/complementary approach can be drawn from conflict resolution methods, such as those described in the Theory of Restorative Justice or the Culture of Peace, namely, the Circle of Dialogue Technique (Pranis, 2011), among others. These insights offer valuable perspectives on tailoring cooperation and conflict resolution strategies to the particularities of local power structures.

Illustrating instances where local conflicts over groundwater resources were successfully resolved through cooperative agreements becomes imperative. Likewise, it is relevant to understand and innovate in the way of how agreements are carried out and how cooperation can be made possible, using tools that can improve the reach of MAR systems and people’s life.

Case studies, such as CC, CDC, and CID (2008), summarized in Annex A1, exemplify how such agreements define roles, responsibilities and obligations related to MAR tests, encompassing installation, maintenance, permits and post-test reporting. This case underscores the effectiveness of interlocal cooperation for joint endeavours, emphasizing joint powers among public agencies and special-purpose districts for shared objectives. The need for effective communication and coordination is essential to this collaborative framework, as evidenced by the provision of information to ensure seamless operations and transparency. Financial reimbursement mechanisms further underscore the importance of accountability, fostering fairness and shared responsibility for MAR. The inclusion of a dispute resolution mechanism, involving designated representatives and, if necessary, an arbitrator, emphasizes the importance of addressing conflicts promptly and fairly to maintain the integrity of the agreement. Additionally, the incorporation of a hold-harmless agreement underscores the commitment to assuming liability for one's actions, promoting a responsible and accountable approach. Lastly, well-defined termination clauses provide a structured framework for ending the agreement under various circumstances, safeguarding the interests of all parties involved and offering a blueprint for addressing defaults, public convenience and insufficient funds.

This highlights how proactive engagement and consensus-building among diverse stakeholders led to mutually beneficial outcomes in aquifer management. These instances serve as a reference, demonstrating that cooperative agreements can transcend conflicts, fostering sustainable solutions rooted in collective decision-making. However, it is also important to recognize that conflicts themselves are neither good nor bad, but are situations that, when properly handled, can boost the quality of the agreements and increase the credibility of decision makers and beneficiaries involved in MAR initiatives building a sense of trust and cooperation among stakeholders.

2.3. Socio-legal and political science perspectives on MAR governance

MAR is a multifaceted process that involves several factors. However, the significance of local institutions and governance structures cannot be overstated in determining the management of aquifers. It is essential to know the interplay between local institutions, legal frameworks and political dynamics, and how they impact groundwater use and conservation at the community level.

Local institutions, such as municipal bodies and community-driven organizations, have a significant impact on MAR initiatives. The AGREEMAR Deliverable D1.1 highlights the role and importance of these institutions in defining the management of aquifers (Conrad et al., 2022). The success and sustainability of MAR projects depend on the degree of decentralization in decision-making, the allocation of responsibilities, and the inclusivity of representation within these local institutions (Aarnoudse et al., 2012; Kemper, 2007; Kiparsky et al., 2017), among other factors. Furthermore, the legal authority given to these local bodies should not be underestimated.

Community involvement is crucial for the success and sustainability of aquifer management initiatives. The transformative impact of community engagement in shaping policies and practices has been demonstrated by successful groundwater management projects (Huang et al., 2013; Maheshwari et al., 2014). As primary stakeholders, communities contribute valuable local knowledge that often surpasses the understanding derived from technical assessments alone. Their intimate connection to the aquifer ecosystem positions them as invaluable collaborators in decision-making processes. When communities actively participate in the formulation of aquifer management strategies, there is a discernible shift towards more sustainable groundwater practices (Dillon et al., 2022). However, it is necessary to be vigilant in dealing with communities, who are always perceptive and reactive if they feel they are only being solicited for knowledge, which is why it is essential to create bonds of trust, to fulfil promises of benefits and to develop a respectful and human interrelation with all communities and their expertise.

The effective implementation of MAR governance requires a special focus on understanding and addressing the social, legal and political impacts that institutions and frameworks may have on communities.

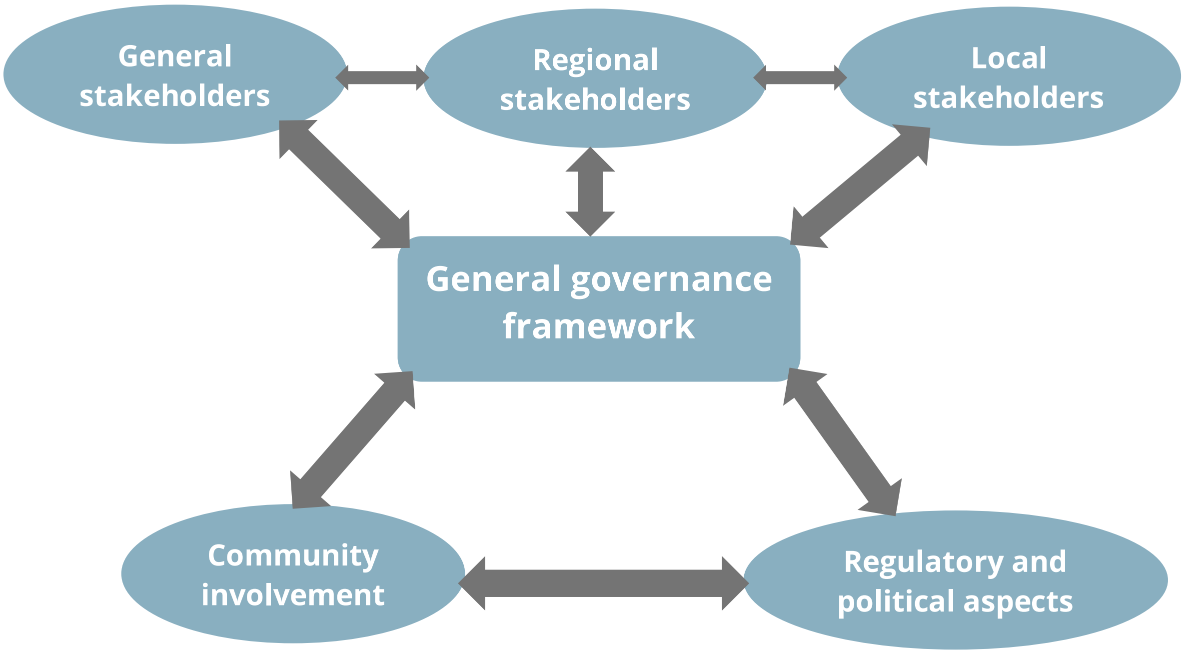

Figure 1. Socio-legal and political interactions for MAR.

Regulatory frameworks are instrumental in establishing the rules that govern groundwater extraction, allocation and recharge. Success stories from various regions underscore the positive impact of well-crafted regulations. California's Sustainable Groundwater Management Act (SGMA), for instance, represents a paradigmatic shift in groundwater governance. By mandating the formation of Groundwater Sustainability Agencies and requiring the development of comprehensive Groundwater Sustainability Plans, SGMA has set a precedent for proactive and holistic groundwater management (Miro & Famiglietti, 2019).

In areas where regulations have clear guidelines on the amount of groundwater that can be extracted, strict monitoring mechanisms, active vigilance, and severe penalties for non-compliance, there is evidence of better control over groundwater use. These regulatory frameworks provide a structured approach to balancing the needs of different stakeholders, including agriculture, industry and urban areas, thereby promoting sustainable practices (Nelson & Quevauviller, 2016). Tailoring regulations to local conditions and fostering stakeholder engagement in the regulatory process are essential strategies for improving their efficacy.

Successful regulatory frameworks often incorporate flexibility, allowing for adaptive management in response to changing aquifer dynamics, climate variations, social dynamics and emerging technologies. Learning from both success and failure, regulatory approaches can evolve to become dynamic instruments that not only control abstraction, but also promote the sustainable and equitable use of precious groundwater resources (Brodie et al., 2007; Thomann et al., 2020).

3. Reviewing existing theoretical approaches to MAR governance

MAR governance has evolved through various global experiences, revealing key lessons that underline the need for resilient, adaptive and sustainable practices. One of the key lessons is the need for comprehensive regulation, illustrated by state-specific policies in regions such as Arizona (the Underground Storage and Recovery Act, 1986, and the Underground Water Storage, Savings and Replenishment Program, 1994), California and Florida. These policies require permits covering the storage, recovery and use of water, underlining the importance of a regulatory framework up to date with the best technological practices, that guarantee the quality of physical process and ethically reliable practices to guarantee the quality of non-physical process, tailored to local contexts. The implementation of risk-based guidelines in the Australian national guidelines for MAR (NRMMC, EPHC and NHMRC 2009) highlights the paramount importance of prioritizing human health and environmental protection in risk management activities. These guidelines, based on World Health Organization principles, comprehensively address water quality risks, demonstrating the importance of a proactive approach to risk management in MAR projects. International collaborative efforts are essential to standardize MAR governance practices, foster a common understanding of the best practice and create a united front in the face of challenges posed by varying regulations from country to country (Casanova et al., 2016; Dillon et al., 2019).

Adaptability to local contexts is a recurring topic in MAR projects (Dillon et al., 2019). State-specific policies illustrate the need to adapt MAR governance frameworks to regional challenges and opportunities. This adaptability ensures that regulatory measures are aligned with the unique characteristics of each region and with the culture, necessities and aspirations of the individuals who inhabit it, maximizing the effectiveness and relevance of MAR initiatives. Monitoring and accountability are fundamental, as well as the structuring of bonds of trust for the intentional commitment of all involved for MAR good governance to be achieved. Ongoing monitoring and the establishment of public repositories of information are essential to ensure the smooth running of MAR projects. This not only increases transparency but also provides valuable data for future research and improved governance, forming the basis for the continued success of MAR initiatives (Dillon et al., 2019; Rossetto, 2016). The guarantee of this success will also be related to the existence of public policies that ensure quality environmental education, in general, and on water issues, in particular, for the entire population, capable of showing MAR in the context of the water "natural" cycle context, thus giving the population a sense not only to accept MAR, but to be committed with it.

Public engagement is also proving to be an essential factor, as illustrated by the manuals and guides developed in India (CGWB, 2007). Involving communities in the planning and implementation of MAR projects is crucial to their success, as it ensures that initiatives are well received and correspond to the needs and expectations of local populations. And to come close to the people to know their needs, soft systems methodologies (SSM) should be incorporated in all stages of developing MAR systems. AGREEMAR will present in a practical way how SSM can be incorporated in one of its case studies in Portugal.

MAR governance frameworks must give priority to practices that preserve groundwater quality, prevent excessive pressure, and make a positive contribution to water resource management, environmental protection and restoration. Incorporating these concepts into governance frameworks creates a roadmap for resilient, adaptive and sustainable practices, addressing current and future water resource management challenges through the socio-legal and political science perspectives of MAR governance.

4. Proposed general governance framework for MAR

The AGREEMAR project proposes a whole set of concepts that need to be taken into consideration to generate a general governance framework for MAR. The four main aspects to be considered are technical, social, economic and regulatory, and these concepts should be interrelated to reach agreements for MAR. The technical part encompasses the identification of potential MAR sites and the assessment of the MAR effects on the rest of water uses in the region, among other aspects. This technical part is interconnected with the social part, which manifests itself in terms of a tool for convincing or discussing with stakeholders the possibility of implementing MAR and thus guaranteeing transparency. Considering the legislation of the MAR site involved and considering the interaction arising with the technical, economic and social parts, agreements for MAR can be drawn up.

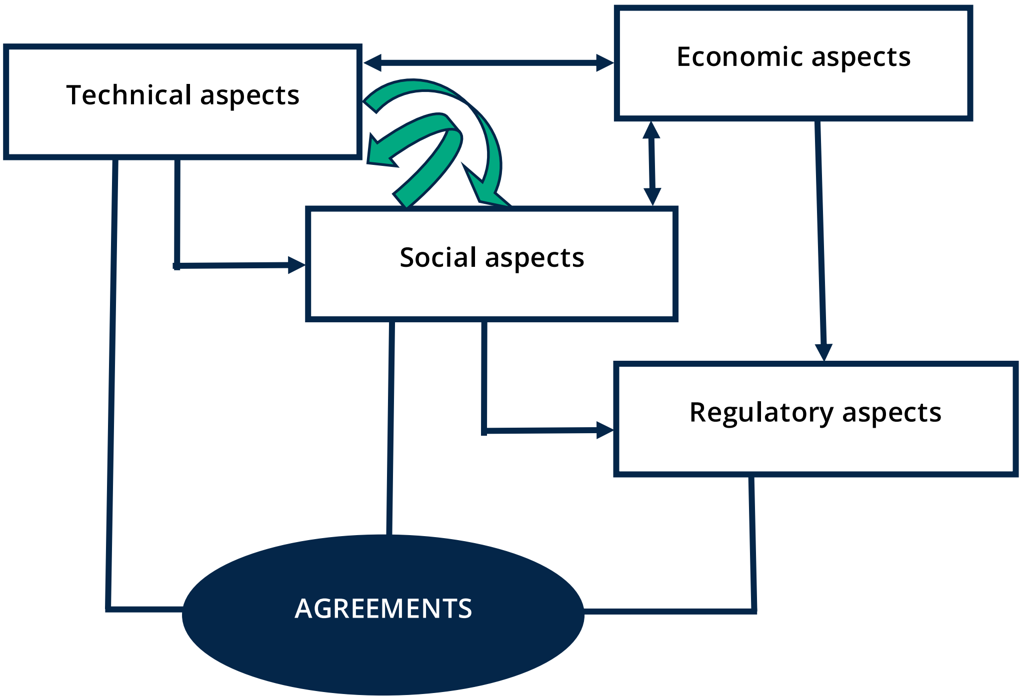

Figure 2. Elements to be considered when drafting MAR agreements.

Among the four essential pillars for MAR agreements according to the AGREEMAR vision, the technical side requires the use of tools such as feasibility maps, groundwater models and water management models, among others. The economic aspect covers the understanding of the costs and benefits, and the financial situation of MAR projects, including cost allocation. By comprehensively assessing economic factors, stakeholders will be able to make informed decisions about investment, resource allocation and the viability of MAR initiatives. These elements are crucial to ensure the effective and sustainable implementation of MAR. On the social side, stakeholder identification, engagement, and recognition of the direct or indirect beneficiaries of MAR is essential. Active stakeholder participation contributes to the success of initiatives, while clarity about beneficiaries fosters an inclusive approach to water management. At this point, it is important to understand that the quality of participation, as well as the quantity of direct or indirect benefits provided by MAR systems, are important social indicators to be observed for continuous improvement of these initiatives. It is interesting to note that there is a synchronicity between the most important technical indicators, based on a survey carried out with stakeholders, which are the quality and quantity of water made available by MAR systems, and the main social indicators, designed based on the central objectives of the AGREEMAR project, namely: being a participatory process to generate shared benefits.

Finally, the regulatory aspect manifests itself through existing laws and regulations governing aquifer recharge. Understanding and respecting these legal frameworks is imperative to ensure compliance and avoid negative impacts. Thus, the drafting of agreements for MAR must consider these four interconnected dimensions to guarantee the success and sustainability of MAR initiatives. To delve deeper into these concepts, the following sections take a step-by-step look at each aspect to be considered and how it should be applied (Figure 3).

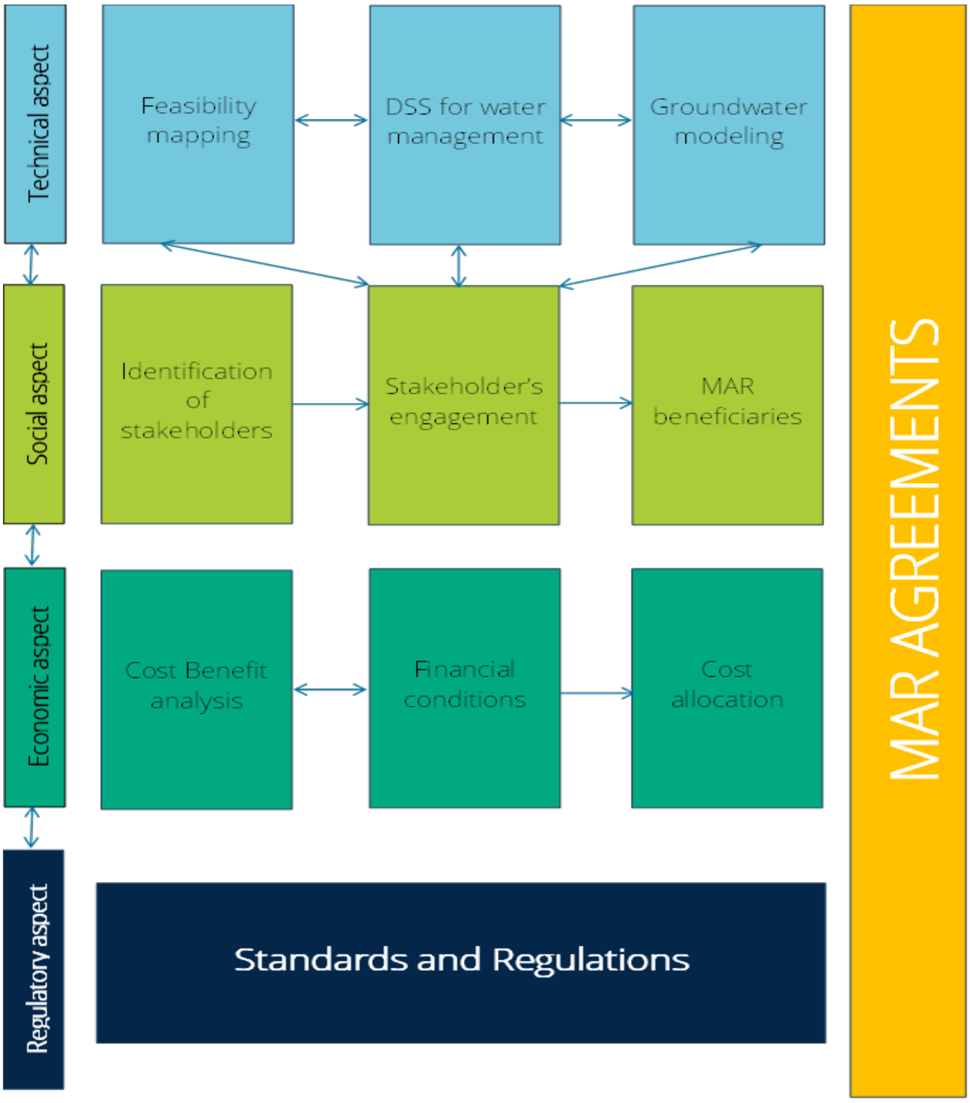

Figure 3. AGREEMAR's vision for drafting MAR agreements.

4.1. Preliminary assessment

This primary phase is an imperative step in the MAR process. It requires an in-depth analysis of the subsurface to understand the geological and hydrogeological conditions of potential MAR sites. The use of advanced geophysical and geochemical techniques enables a nuanced understanding of the subsurface, facilitating the selection of sites with optimal conditions for effective aquifer recharge.

To strengthen this analysis, it is essential to integrate environmental aspects and assess the region's water needs. Socio-economic analysis and early community engagement are also crucial. In addition, referencing previous studies on the proposed site enhances understanding, demonstrating an informed approach based on existing data. This phase, although highly prospective, can also be based on previous studies carried out on the site to be adapted to MAR, consolidating the knowledge base for effective and sustainable implementation.

4.2. Identification of potential MAR sites

Potential MAR sites can be identified using MAR feasibility maps. This approach may involve a comprehensive matrix of feasibility criteria, through a multi-criteria analysis taking into account various factors in the biophysical, technological, social, economic, environmental, hydrological, institutional and financial dimensions. More details on the methodology used to draw up these feasibility maps in the AGREEMAR project are presented in Deliverables D2.1 (Panagiotou et al., 2022), D2.2 (Martins et al., 2022) and D2.3 (Chekirbane et al., 2023).

Figure 4. The general concept of MAR site suitability mapping.

Feasibility maps serve as a confirmation tool, visually representing the results of the entire assessment, including the social part, which translates into stakeholder involvement. Confirmation of feasibility includes an extensive examination of the matrix scores, which stakeholders will play a part in defining. High scores in the feasibility grid confirm that a site is suitable for MAR implementation.

Once a MAR pilot project has been successfully implemented and monitored, the feasibility maps become a valuable tool for replication. The replication approach involves adapting the matrix to the specific conditions of each region while retaining a standardized evaluation framework. This integrated methodology ensures a well-informed decision-making process, aligning MAR initiatives with the unique characteristics and challenges of each region.

4.3. Technical assessments based on numerical modelling

Technical assessment has an important function in the general governance framework for MAR. It forms the scientific basis for the decision-making, design, and implementation of MAR projects. Integrating technical assessments into the general governance framework ensures that MAR initiatives are based on hydrogeological principles, take account of environmental factors, and are aligned with broader water resource management objectives. This involves defining hydrogeological criteria for site selection, developing technical standards, and setting up monitoring systems to assess groundwater levels and quality, as well as environmental impacts (Ringleb et al., 2016; Zhang et al., 2020). The governance framework must be supported by decision support systems (DSS) and groundwater models, which play an essential role in improving technical decision-making. Modeling is generally carried out during the approval or planning stages of a MAR project to assess its feasibility on the proposed site (Ringleb et al., 2016).

DSS integrate data and models to provide real-time information and facilitate adaptive management of groundwater management initiatives. In the case of the AGREEMAR project, the AQUATOOL DSS is being used to analyze the effects of MAR on the rest of water uses in the basin, considering the evolution of the aquifers, the interactions between surface water, groundwater and non-conventional water resources, and other environmental aspects for different MAR strategies. AQUATOOL comprises several modules for hydrological simulation, groundwater simulation, management simulation and optimization, economic evaluation, water quality assessment and environmental assessment (Andreu et al., 1996; Paredes-Arquiola et al., 2013; Momblanch et al., 2016; Ghannem et al., 2023b; Ghannem et al., 2024). Setting up an AQUATOOL model for the selected MAR site enables the testing of several MAR scenarios, using different water sources for aquifer recharge and assessing the potential benefits on the aquifer, along with the effects on the rest of water uses and environmental aspects in the basin through the assessment of different indicators as those proposed in the AGREEMAR Deliverable D3.1 (Ghannem et al., 2023a). These trials are linked to different operating rules and permits that decision-makers and stakeholders can propose. Using this tool, the impact of the MAR can be visualized, enabling monitoring of its effects on the basin. This ensures a framework of trust and transparency with all parties included in the MAR system, providing a coherent modeling environment that enables easy collaboration, the choice of solutions after conjunctive analysis of scenarios and supports participative stakeholder involvement in decision-making. In fact, this is one of the pillars to ensure an effective and positive connection between general stakeholders (GS), regional stakeholders (RS), and local stakeholders (LS), and to facilitate the endorsement and approval of a MAR activity by GS and RS.

Groundwater models contribute to comprehensive feasibility assessments, site selection and predictive modeling to compare different MAR techniques and operational schemes (Ringleb et al., 2016). As a groundwater model, the AGREEMAR project uses the INOWAS platform to study the general behavior of aquifers in the case studies. This modeling approach is entirely participatory, involving simulation of the impact of proposed MAR concepts, generated after interaction with stakeholders. It can, for example, provide them with information about the aquifer's infiltration capacity and the effectiveness of the MAR system. The assessment of environmental benefits in the groundwater systems evaluated could be validated through consultations with regional stakeholders. This participatory modeling will enable constant updating and adaptive scenarios for MAR implementation, thanks to the contributions of stakeholders and the expertise of modelers.

Technical assessments are also required to analyze and compare possible solutions for MAR. This manifests itself in terms of choosing the right recharge technique for the study site, and this will depend on geology, water quality, legislation, etc. Some methods refer to water infiltration, such as spreading methods (infiltration ponds, ditches and furrows, and excess irrigation), induced bank filtration and recharge wells, whereas other techniques aim primarily at intercepting water, such as in-channel modifications (recharge dams), water spreading and runoff harvesting (rooftop rainwater harvesting structures, trenches, barriers and bunds). In this context, it is relevant to foster the use of nature-based solutions (NBS) as much as possible.

4.4. Identification of stakeholders and their relationships

Stakeholder identification and engagement requires a nuanced approach, recognizing the cultural and social complexities of the region. This is crucial for the successful and sustainable implementation of the MAR projects (Dillon et al. 2022).

The relevance of stakeholder engagement has already been highlighted in the AGREEMAR Deliverable 1.1 (Conrad et al., 2022). The methodology adopted at this stage is based on the results of a detailed stakeholder identification and analysis through documentation research, and stakeholder interviews and workshops as part of a participatory co-creation process. The engagement strategy and plan include the following main elements: firstly, defining the specific engagement objectives for the MAR project. Secondly, identification of relevant stakeholders in the MAR project region. This is followed by an analysis and prioritization of the key stakeholder groups identified in the regions for sustainable engagement. A strategy development and engagement plan associated with the MAR project is followed. In the end, a multi-stakeholder approach can be used to identify the most engaging priority stakeholders for MAR, as well as the format of engagement and how to manage conflicts if they arise. More details on the stakeholder engagement strategy proposed in the AGREEMAR project are provided in Deliverable D1.1 (Conrad et al., 2022).

Figure 5. Four-step approach towards a stakeholder engagement strategy and plan (Conrad et al., 2022).

Once the stakeholders are identified, it is necessary to understand the dynamics between them, which will allow the identification of the potential beneficiaries of the MAR. It is first necessary to identify the key factors for water demand and supply, and the associated stakeholders in the MAR project region. These may include agricultural activities, industrial processes, domestic water use and environmental considerations, etc. Local communities, water experts and relevant stakeholders should be consulted to draw up a comprehensive list of factors. Next, it is essential to collect data on the water-related activities of each stakeholder. This data can cover water consumption patterns, reliance on groundwater, contribution to water pollution and dependence on specific water sources, among others. The analysis of those elements can be used to identify hotspots where water demand is high, or where several stakeholders are interconnected. This indicates the areas where water-related challenges are the greatest and are likely to be the focus of MAR interventions, which will help in prioritizing beneficiaries according to their dependence on groundwater, their vulnerability to water scarcity and the potential positive impact of MAR projects. Constellation analysis could be considered as an option for analyzing the interconnections between stakeholders and identifying potential beneficiaries (e.g., Schäfer & Kröger, 2016).

The cost and benefits distribution of MAR solutions among beneficiaries is essential. As there are both direct and indirect beneficiaries, it is essential to recognize that the sharing of MAR costs will not be uniform. To achieve fair cost-benefit sharing, stakeholders need to be fully aware of the specific benefits they can derive from MAR systems. This means clearly defining the parties involved and exploring their common interests in the success of MAR installations, which will help to justify and communicate cost allocation effectively. Setting out clearly the benefits of MAR installations, and identifying each party's willingness to contribute financially, provides the basis for joint agreements. This process of communication and commitment not only ensures a fair sharing of costs and benefits, but also fosters an environment of cooperation that enables stakeholders to voluntarily reach agreements.

The emphasis on clear communication and mutual understanding provides the basis for sustainable partnerships, in which all parties are well informed of the costs involved and the benefits they can expect. This approach enables identified beneficiaries to be integrated into the overall planning and implementation of MAR projects and adapt interventions to meet the specific needs and challenges identified, ensuring that the benefits of MAR are distributed equitably. Methodologies based on game theory can be used to design a fair and equitable distribution of costs among stakeholders (e.g. Sechi et al., 2013). Inspired and motivated by the game theory, in which all participants win, we seek to advance through the AGREEMAR methodology, in order to improve the governance of water resources, adding an additional "player" (the ecosystem), that should win in all "games" to make possible the victory of the other "players". The water cycle is essential to make life possible in the Earth planet and to recover its intrinsic characteristic of being a finite natural resource, but renewable, needing to be well managed using technologies inspired in nature, making agreements based in ecological justice, which is not opposed to human justice, quite the contrary, they support each other.

It is necessary to consider the fact that the principles that govern natural systems and anthropic systems are not the same, therefore, the interaction between technological elements and social elements does not occur spontaneously, immediately. This interaction will be possible by the application of a methodology capable of carrying out translation work (Santos, 2002) so that two different cultures can communicate and, the result of this understanding, will be agreements and a governance framework for MAR systems. Systems appears in the plural because the social component gives each MAR initiative a unique and unrepeatable character, typical of an ecosystem and a cultural diversity, although a general methodology can be followed and applicable to different projects, governance scales and realities. This is the aforementioned CA, which is part of the group of soft systems methodologies that have been applied in several countries in scientific, technological innovation and sustainability projects. In Brazil it has been successfully used, especially in the management of water resources, among other areas.

4.5. Economic considerations

Economics aspects are one of the key considerations in the general governance framework for MAR agreements. By carrying out the cost-benefit analyses, it is possible to find out whether the benefits produced by MAR projects are greater than their costs and so their economic feasibility is guaranteed. Examination of financial conditions and cost allocation ensures that resources are divided efficiently and fairly among stakeholders, promoting equal participation in MAR projects as well as their support. Economic considerations contribute to long-term sustainability for MAR projects by guiding decisions on financing, investment prioritization and revenue generation strategies.

4.6. Standards and regulations

Standards and regulations provide a structured, legal framework to guide the planning, implementation and monitoring of MAR initiatives. This involves working alongside local, national and international authorities to ensure that the governance framework is aligned with best practices and to harmonize it with existing water management policies.

To achieve agreements for MAR, it is imperative to take these standards and regulations into consideration to ensure legality, sustainability and compliance. For that purpose, it is essential to carry out a thorough analysis at local, national and international levels. This helps identify the legal requirements with which the agreements must comply. It is also advisable to construct a contractual framework for the agreement, considering the standards and regulations identified. It is crucial to clearly spell out the responsibilities of each party, monitoring arrangements, environmental requirements, and any other regulatory issues. Subjecting the agreement to legal review, to ensure that it complies with current legal standards, is essential, so an important section of the agreements should be the explicit declaration of the standards and regulations that affect the MAR action. This may even include the legal aspects of different countries, if it is an international action, and bilateral agreements, if they exist.

4.7. Illustrative agreement that could be drawn up for MAR / Model agreement for MAR

It is relevant to consider three categories of agreements, each corresponding to a specific stage in the development of the MAR system. Firstly, agreements for investigation focus on the initial exploration of the feasibility of MAR. To implement these agreements, feasibility maps and groundwater models can be used to assess the suitability of implementing MAR strategies. These agreements mark the start of the process and lay the foundations for more detailed steps to follow.

Next, agreements to initiate in-depth studies are required once the decision in favor of MAR has been made. These in-depth studies include the detailed identification of stakeholders, securing their engagement, and the use of water management models to assess the potential impacts of MAR on the rest of water uses and environmental restrictions in the river basin. At this stage, it is imperative to take into consideration standards and legislation related to MAR to ensure project conformity and sustainability. Most countries require an environmental impact assessment.

Finally, agreements for the infrastructures construction, maintenance, monitoring and real time operation of the MAR system represent the phase when the MAR system comes into action. These agreements include the definition of the beneficiaries of MAR and the distribution of costs, specifying how the MAR system complies with current legislation throughout its operational lifecycle, among other aspects. The planning of this phase must be rigorous to ensure successful, sustainable implementation, in line with the commitments made at previous stages.

These agreements could take two distinct forms, i.e. explicit and implicit, depending on the nature and complexity of the MAR project. Explicit agreements involve formal, clearly defined commitments between stakeholders, specifically detailing the responsibilities, rights and obligations of each party throughout the various phases of the project. These explicit agreements offer greater transparency and a solid legal basis, reinforcing trust between the parties involved.

On the other hand, implicit agreements can arise from unwritten agreements or mutual understandings between parties, often established through informal collaborative practices. Although less formal than explicit agreements, implicit agreements can play a crucial role in the successful implementation of MAR, particularly in contexts where established relationships and shared understanding already exist. However, it is imperative that even in the case of implicit agreements, fundamental principles, standards and applicable regulations are always taken into consideration to ensure ongoing compliance and transparent project management.

Each type of agreement contributes sequentially to the full realization of the MAR project, offering a progressive and structured approach to the successful development and implementation of MAR. This evolutionary approach ensures not only conformity with standards and legislation, but also ongoing stakeholder engagement, thorough assessment of potential impacts, and transparent, efficient project management at every stage of development.

5. Conclusions

Successful governance of MAR requires a holistic approach that considers the complex interplay of technical, social, economic, and regulatory dimensions. The general governance framework proposed by the AGREEMAR project in this document offers a comprehensive guide to drafting agreements for MAR. Key aspects such as stakeholder engagement and decision-making, identification of potential and feasible MAR sites, technical assessments based on numerical modelling, economic considerations such as financial implications, cost allocation, cost-benefit analyses, and compliance with standards and regulations, are crucial to ensure the success and sustainability of MAR initiatives.

By reviewing case studies and global experiences, as well as contributions from general stakeholders and regional stakeholders, the document highlights the importance of regulatory frameworks for achieving sustainable groundwater management. Furthermore, a step-by-step approach to MAR agreements is proposed: preliminary investigation, in-depth studies, and execution/operation. These agreements, whether explicit or implicit, are vital for studying, initiating, and operationalizing MAR projects. The framework acknowledges the importance of transparency and legal basis for explicit agreements, while recognizing the role of shared understanding in implicit agreements.

The general governance framework proposed in this deliverable offers a structured and adaptable approach to the governance of MAR, fostering collaboration between stakeholders and ensuring the long-term success of aquifer recharge initiatives.

6. References

Aarnoudse, E., Bluemling, B., Wester, P., & Qu, W. (2012). The role of collective groundwater institutions in the implementation of direct groundwater regulation measures in Minqin County, China. Hydrogeology Journal, 20(7), 1213.

Andreu, J., Capilla, J., & Sanchís, E. (1996). AQUATOOL, a generalized decision-support system for water-resources planning and operational management. Journal of hydrology, 177(3-4), 269-291.

BOE (2023). Real Decreto 665/2023, de 18 de julio, por el que se modifica el Reglamento del Dominio Público Hidráulico, aprobado por Real Decreto 849/1986, de 11 de abril; el Reglamento de la Administración Pública del Agua, aprobado por Real Decreto 927/1988, de 29 de julio; y el Real Decreto 9/2005, de 14 de enero, por el que se establece la relación de actividades potencialmente contaminantes del suelo y los criterios y estándares para la declaración de suelos contaminados. https://www.boe.es/diario_boe/txt.php?id=BOE-A-2023-18806.

Brodie, R., Sundaram, B., Tottenham, R., Hostetler, S., & Ransley, T. (2007). An adaptive management framework for connected groundwater-surface water resources in Australia. Bureau of Rural Sciences, Canberra.

Burchi, S. (2017). Legal principles and legal frameworks related to groundwater. In Advances in groundwater governance (pp. 119-136). CRC Press.

Casanova, J., Devau, N., & Pettenati, M. (2016). Managed aquifer recharge: an overview of issues and options. Integrated groundwater management: Concepts, approaches and challenges, 413-434.

CC, CDC, and CID (2008). Interlocal Agreement Regarding Artificial Recharge Test via Irrigation Ditches. Clallam County, WA, USA.

CGWB (2007) Manual on artificial recharge of ground water. Central Ground Water Board, New Delhi. https://cwas.org.in/resources/file_manager/module_3-3_6_manual_on_artificial_recharge_of_ground_water_cpcb.pdf.

Chekirbane, A., Khemiri, K., Panagiotou, C.F., Martins, T.N., Leitão, T.E., Eisenreich, S., Stefan, C. (2023). AGREEMAR Deliverable D2.3: MAR feasibility maps validated for each demo region. Available online at https://www.agreemar.inowas.com/deliverables.

Conrad, A.; Heim, R.; Helling, L. (2022). AGREEMAR Deliverable D1.1: Stakeholder engagement strategy and plan. Available online at https://www.agreemar.inowas.com/deliverables.

Dillon, P., P. Pavelic, D. Page, H. Beringen, and J. Ward (2009). Managed aquifer recharge: An introduction. Waterlines Report Series number 13, February 2009, National Water Commission, Canberra, Australia, https://recharge.iah.org/files/2016/11/MAR_Intro-Waterlines-2009.pdf.

Dillon, P., Stuyfzand, P., Grischek, T., Lluria, M., Pyne, R. D. G., Jain, R. C., ... & Sapiano, M. (2019). Sixty years of global progress in managed aquifer recharge. Hydrogeology journal, 27(1), 1-30.

de los Cobos, G. (2018). The Genevese transboundary aquifer (Switzerland-France): The secret of 40 years of successful management. Journal of Hydrology: Regional Studies, 20, 116-127.

Dillon, P., W. Alley, Y. Zheng, and J. Vanderzalm (2022). Managed Aquifer Recharge: Overview and Governance. IAH Special Publication. https://recharge.iah.org/ ISBN 978-1-3999-2814-4

Escalante, E. F., Stefan, C., Brown, C. J., & Hutchinson, A. (2023). Managed Aquifer Recharge: A Key to Sustainability. Water, 15(23), 4183.

Gambi, T., Chaves, R. (2017). "Development Ethics" as an Interdisciplinary Research Proposal. Development in Question number 39, Abril 2017, São Paulo, Brazil, http://dx.org/10.21527/2237-6453.2017.39.6-31

Ghannem, S., Bergillos, R. J., Andreu, J., Paredes-Arquiola, J., & Solera, A. (2023a). AGREEMAR Deliverable D3.1: Preliminary analysis of indicators and methodologies for decision-making. Available online at https://www.agreemar.inowas.com/deliverables.

Ghannem, S., Bergillos, R. J., Paredes-Arquiola, J., Martínez-Capel, F., & Andreu, J. (2023b). Coupling hydrological, habitat and water supply indicators to improve the management of environmental flows. Science of The Total Environment, 898, 165640.

Ghannem, S., Paredes-Arquiola, J., Bergillos, R. J., Solera, A., & Andreu, J. (2024). Assessing the Effects of Environmental Flows on Water Quality for Urban Supply. Water, 16(11), 1509.

Grigg, S. (2011). Water governance: from ideals to effective strategies. Water International number 7(36), 799-811.

Huang, Q., Wang, J., Rozelle, S., Polasky, S., & Liu, Y. (2013). The effects of well management and the nature of the aquifer on groundwater resources. American Journal of Agricultural Economics, 95(1), 94-116.

Jarvis, W. T. (2014). Contesting hidden waters: Conflict resolution for groundwater and aquifers. Routledge.

Kemper, K. E. (2007). Instruments and institutions for groundwater management. The agricultural groundwater revolution: Opportunities and threats to development, 153-172.

Kiparsky, M., Milman, A., Owen, D., & Fisher, A. T. (2017). The importance of institutional design for distributed local-level governance of groundwater: The case of California's sustainable groundwater management act. Water, 9(10), 755.

Kurki, V. (2016). Negotiating groundwater Governance: lessons from contentious aquifer recharge projects.

LeRoy, P. (1995). Troubled waters: population and water scarcity. Colo. J. Int'l Envtl. L. & Pol'y, 6, 299.

Lukenga, W. (2015). Water Resource Management. Munster: Walter Lukenga & bookboon. com.

Maheshwari, B., Varua, M., Ward, J., Packham, R., Chinnasamy, P., Dashora, Y., ... & Rao, P. (2014). The role of transdisciplinary approach and community participation in village scale groundwater management: insights from Gujarat and Rajasthan, India. Water, 6(11), 3386-3408.

Martins, T.N., Panagiotou, C.F., Stefan, C., Chkirbene, A. (2022). AGREEMAR Deliverable D2.2. Participative methodology for criteria selection and weighting in MAR site feasibility mapping. Available online at https://www.agreemar.inowas.com/deliverables.

Mechlem, K. (2016). Groundwater governance: The role of legal frameworks at the local and national level—Established practice and emerging trends. Water, 8(8), 347.

Miro, M. E., & Famiglietti, J. S. (2019). A framework for quantifying sustainable yield under California's Sustainable Groundwater Management Act (SGMA). Sustainable water resources management, 5, 1165-1177.

Momblanch, A., Connor, J. D., Crossman, N. D., Paredes-Arquiola, J., & Andreu, J. (2016). Using ecosystem services to represent the environment in hydro-economic models. Journal of Hydrology, 538, 293-303.

Nelson, R., & Quevauviller, P. (2016). Groundwater law. Integrated groundwater management: Concepts, approaches and challenges, 173-196.

NRMMC, EPHC and NHMRC (2009). Australian Guidelines for water recycling, managing health and environmental risks, vol 2C: managed aquifer recharge. Natural Resource Management Ministerial Council, Environment Protection and Heritage Council National Health and Medical Research Council, July 2009, 237 pp. https://www.waterquality.gov.au/sites/default/files/documents/water-recycling-guidelines-full-21.pdf

OECD (2015). OECD Principles on Water Governance Welcomed by Ministers at the OECD Ministerial Council Meeting on 4 June 2015. Directorate for Public Governance and Territorial Development, Organization for Economic Cooperation and Development, Paris. https://www.oecd.org/cfe/regionaldevelopment/OECD-Principles-on-Water-Governance.pdf

Ohlhorst, D., & Schön, S. (2015). Constellation analysis as a means of interdisciplinary innovation research–theory formation from the bottom up. Historical Social Research/Historische Sozialforschung, 258-278.

Panagiotou, C.F., Chkirbene, A., Stefan, C., Martins, T.N., Leitão, T.E. (2022). AGREEMAR Deliverable D2.1: Matrix of feasibility criteria for managed aquifer recharge. Available online at https://www.agreemar.inowas.com/deliverables.

Paredes-Arquiola, J., Martinez-Capel, F., Solera, A., & Aguilella, V. (2013). Implementing environmental flows in complex water resources systems–case study: the Duero river basin, Spain. River Research and Applications, 29(4), 451-468.

Pereira, L. S., Cordery, I., & Iacovides, I. (2009). Coping with water scarcity: Addressing the challenges. Springer Science & Business Media.

Pranis, K. (2011). Restorative justice and peacebuilding circles: facilitator´s guide. Porto Alegre. Brazil.

Ringleb, J., Sallwey, J., & Stefan, C. (2016). Assessment of managed aquifer recharge through modeling—A review. Water, 8(12), 579.

Rittel, H. (1973). Dilemmas in a general theory of planning. 155-169.

Rodorff, V., Siegmund-Schultze & M., Gomes, E. T. A. (2015). Multi-level governance challenges in the São Francisco watershed: inter and transdisciplinary perceptions In Portuguese: Governança da bacia hidrográfica do Rio São Francisco: Desafios de escala sob olhares inter e transdisciplinares. Revista Brasileira de Ciências Ambientais (Online), 36, 19–44. https://doi.org/10.5327/Z2176-947820151003

Rogers, P., & Hall, A. W. (2003). Effective water governance (Vol. 7). Stockholm: Global water partnership.

Rossetto, R. (2016). Managed aquifer recharge in Italy. Electronic Supplementary Material-Hydrogeology Journal Sixty years of global progress in managed aquifer recharge, 28.

Santos, B. (2002). For a sociology of absences and a sociology of emergencies. Journal of social science number 63, October, 237-280.

Schäfer, M., & Kröger, M. (2016). Joint problem framing in sustainable land use research: Experience with Constellation Analysis as a method for inter-and transdisciplinary knowledge integration. Land Use Policy, 57, 526-539.

Sechi, G. M., Zucca, R., & Zuddas, P. (2013). Water costs allocation in complex systems using a cooperative game theory approach. Water Resources Management, 27, 1781-1796.

The State Council of the Republic and Canton of Geneva and The Prefect of Haute-Savoie (2008). Arrangement on the Protection and Recharge of the Franco-Swiss Genevois Aquifer of 9 June 1978 between the Republic State Council and Canton of Genève and the Prefect of Haute-Savoie' of June 9th, 1978.

Thomann, J. A., Werner, A. D., Irvine, D. J., & Currell, M. J. (2020). Adaptive management in groundwater planning and development: A review of theory and applications. Journal of Hydrology, 586, 124871.

Walter, M. (2010). Managing transboundary aquifers: Lessons from the field. In Research paper collection, International Conference "Transboundary Aquifers: Challenges and New Directions (ISARM) (pp. 1-7).

Williams, B. (2005). Soft Systems Methodologies. http://www.bobwilliams.co.nz/Systems_Resources_files/ssm.pdf

Zhang, H., Xu, Y., & Kanyerere, T. (2020). A review of the managed aquifer recharge: Historical development, current situation and perspectives. Physics and Chemistry of the Earth, Parts A/B/C, 118, 102887.

Zheng, Y., Ross, A., Villholth, K. G., & Dillon, P. (2021). Managing aquifer recharge: a showcase for resilience and sustainability. UNESCO, Paris. Retrieved August, 10, 2021. https://unesdoc.unesco.org/ark:/48223/pf0000379962.locale=en

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Annex

A1. Example of interlocal agreement: Clallam County

This example illustrates an interlocal agreement regarding artificial recharge test via irrigation ditches (CC, CDC, and CID, 2008). It entered into by and between Clallam County, the Clallam Ditch Company (CDC) and the Cline Irrigation District (CID) in support of the "Dungeness Aquifer Storage & Recovery Feasibility Study" sponsored by the Washington Department of Ecology.

CDC and CID own and operate ditches designed to convey water from the Dungeness River, originating from a common diversion point on the west bank, to downstream locations for irrigation, livestock watering, and domestic use. The Interlocal Cooperation Act (Chapter 39.34 RCW) empowers public entities, including special-purpose districts, to jointly exercise their respective powers through intergovernmental agreements. The agreement assembles a set of obligations that various stakeholders have accepted and committed to cooperate with, covering the functions and actions outlined in the agreement.

The agreement includes general obligations primarily directed at Clallam County and secondarily at Clallam Ditch Company and the Cline Irrigation District. These obligations revolve around three main aspects: artificial recharge test facilities and functions, the operation of the artificial recharge test, and the post-test period. Each obligation specifies the requirements that each stakeholder must adhere to. The agreement spans the three phases of the project: before project implementation (study phase), during project implementation (operation phase), and after project implementation (evaluation phase). In this agreement, each stakeholder commits to cooperate in each phase, detailed in different paragraphs that outline the responsibility of each party in each task.

The agreement also addresses disputes, defining the duration of dispute resolution and the representatives involved in the resolution process. In case of non-resolution, an arbitrator designated by the stakeholders must intervene. Another part of the agreement pertains to independent contractors in the project, outlining the formalities and conditions for hiring independents. Following is a paragraph concerning hold harmless, detailing how damages will be addressed in case of negligence by any of the stakeholders. Finally, the last paragraph of the agreement deals with termination, and sets out the various termination conditions.

A2. Example of transboundary agreement: Franco-Swiss Genevois aquifer

This agreement represents a consensus on the protection, use, and monitoring of the Franco-Swiss Genevois aquifer (The State Council of the Republic and Canton of Geneva and The Prefect of Haute-Savoie, 2008). It was established with the common goal of ensuring the future of the Franco-Swiss Genevois aquifer and, consequently, guaranteeing the parties the capacity, to the extent possible, to extract water intended for the drinking water supply of their respective populations. This agreement was forged between the Community of the 'Annemassienne' region, the Community of the 'Genevois' Rural Districts, and the Rural District of Viry, on one side, and the Republic and Canton of Geneva, on the other side.

The agreement acknowledges the need for a concerted management of the aquifer to protect this natural resource and preserve the quality of its waters. It encompasses various points, including the objectives, composition, and functioning of a Commission for the management of the Geneva aquifer, defining the modalities of investment and operation of existing facilities established to optimize aquifer exploitation, especially the construction project of the artificial recharge station. It also establishes the conditions for the withdrawal of each user, and the volumetric and qualitative controls necessary for optimal management. Finally, financial arrangements between the different parties, particularly the terms of the French contribution to the investment and operating costs of the artificial recharge station, are defined.

The agreement enumerates the legislative evolution up to the present date concerning the content of the agreement. These legislations (French and Swiss laws) are used as a basis for the elaboration of this agreement. Given that it is an agreement on a transboundary aquifer, it is necessary for both Swiss and French stakeholders to approve and recognize the laws of each country in this regard.

This agreement defines the administrative, legal, technical, and financial modalities required and is organized into ten chapters. The first chapter concerns the management commission, which includes three articles - one regarding composition, the second regarding the mandate, and the third concerning the operation of this commission.

The second chapter deals with waterworks and equipment, presenting four articles: the first focuses on the inventory of existing equipment and structures; the second article relates to new waterworks and equipment, defining the conditions and monitoring of this implementation process; and the third and fourth articles address the necessity of recording water extractions and water levels.

Moving to the third chapter, extraction forecasts – limits, it contains two articles defining the limits and forecasts of reserved water volume. The fourth chapter is about quantitative and qualitative monitoring of the resource. It presents a single article related to the recording and control of extractions and water levels, specifying who is responsible for control, the frequency of control, and to whom reports should be submitted.

The fifth chapter is about artificial recharge costs sharing, consisting of five articles. Firstly, the French share of artificial recharge costs is defined, including the period of calculation of this cost. Secondly, investment expenditures are defined as the sum of the accounting depreciations of managed assets and remuneration. Thirdly, determination of operational costs enumerates the different components of operational costs. Fourthly, the article concerning the French user's share presents the calculation method of the French share of the artificial recharge costs. Finally, the fifth article of this chapter is focused on terms of payment, defining who is responsible for verifying detailed statements in recharge costs and to whom it should be communicated.

The sixth chapter concerns quality control and pollution abatement, presenting two articles that address water analysis and the warning system. The seventh chapter concerns liability, defining the responsibility of each party. The eighth chapter deals with the duration and termination of the convention, setting the duration of the convention and the possibility of renewal. The ninth chapter is related to applicable law and dispute settlement, outlining the resolution process and the entity responsible for conciliation in case of disputes. Finally, the tenth chapter reports final provisions, encompassing to whom the agreement should be presented, general conditions, and the effective date of the agreement.

A.3 Example of national governance framework: Spanish decree on artificial recharge

The Spanish Decree on Artificial Recharge was established to regulate and organize artificial recharge in Spain (BOE, 2023). It forms part of the regulations governing the public water domain in Spain and includes ten articles designed to frame and regulate this activity. It clearly points out that artificial aquifer recharge is not considered as discharge. To carry it out, it states that authorization is required, which will only be granted if the recharge does not cause groundwater pollution or negative effects linked to overloading, and if it does not create additional pressure due to incompatible abstraction from the original water body.

The decree defines the characteristics of the recharge water source, specifying that any volume of surplus water of appropriate quality may be used, whether it comes from surface water bodies crossing the groundwater body to be recharged, from resources located in other sectors of the groundwater body itself, from neighboring surface or groundwater bodies, or from springs, ponds, treated wastewater or desalinated water.

To initiate artificial recharge projects, the decree authorizes the water authority to initiate recharge applications. These applications may also be proposed by a community of users, a developer, or a private individual. If the recharged water is intended for future use, this circumstance must be included in the corresponding concession.

The decree also regulates the permit process, detailing the information required in an application for artificial recharge. These include justification of the need for recharge, the destination of the stored water, a detailed hydrogeological report, a feasibility report and a full description of the recharge system.

A public consultation phase may be triggered by the basin organization after analysis of the documents, involving a published announcement and one month to gather comments from interested parties. Finally, once the authorization has been granted and the system has been put into service, operators must provide periodic reports on the system's operation and performance, to ensure continuous monitoring of its impact on the hydrogeological system.