Infiltration pond at the Menashe MAR site © Guttman

# Inventory of Fractured-Porous Rock Aquifers for Managed Aquifer Recharge with Desalinated Seawater

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## KEY FINDINGS

The Coastal Aquifer in Israel and Palestine is suitable for seasonal water storage. Managed Aquifer Recharge (MAR) may also help to control seawater intrusion.

Despite being a karst system, the Western Mountain Aquifer has considerable potential for large scale, multi-annual water storage.

Due to low flow velocities, the Disi Aquifer is highly suitable for long-term storage of desalinated water. Additionally, MAR could reduce the rate of increasing salinity and radioactivity concomitant with the decreasing water table.

## MOTIVATION

While desalination plants are designed to produce a constant flux of water, water demand fluctuates. This results in temporary water surpluses. Because the Middle-East relies more and more on desalination for its water supply, these surpluses will increase. Furthermore, the frequency of multi-annual droughts is expected to rise. Therefore, there is an increasing necessity for desalinated water storage to provide management flexibility. The utilization of natural aquifers presents an opportunity to store large volumes of water for extended periods of time at low cost, low evaporation loss, and low risk of contamination. Managed Aquifer Recharge (MAR) with desalinated water is therefore an important measure to balance freshwater supply and demand, increase the resilience of the system to droughts, and enhance the robustness of system management. An inventory is intended to provide criteria and procedures for the evaluation of fractured rock aquifers in Israel, Palestine and Jordan with respect to their suitability for MAR with desalinated seawater to allow for a pre-selection of potential aquifers to be further investigated.

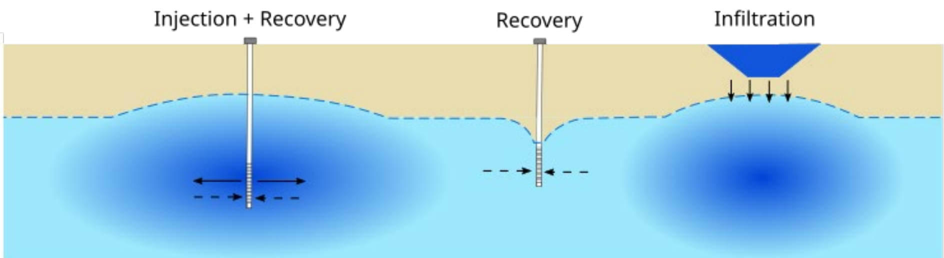


Figure 1: Functional principle of MAR

## METHODOLOGY

For a comprehensive inventory, a holistic evaluation includes not only hydrological, hydrogeological, and water quality criteria, but also economic considerations as well as additional benefits (e.g., ecological benefits, improvements in aquifer management, etc.). These criteria (shown in Table 1) formed the basis in the assessment of different aquifer characteristics. First, available literature on MAR was processed, with a focus on criteria for MAR site selection. Then, aquifer characteristics were collected based on published material, GIS data and documents communicated by the regional project partners. The difference in groundwater levels of the water bearing formations of the aquifers between the times of pre-development and today

| | criteria | WMA | EMA | Coastal Aquifer | Azraq | Disi |
|---|---|---|---|---|---|---|
| hydro-logical | terrain slope | - | - | + | + | - |
| | infiltration capacity | + | + | + | - | n.i.a. |
| | soil contamination | + | n.i.a. | + | - | n.i.a. |
| hydrogeological | Confinement | + | + | + | + | + |
| | hydraulic enclosure | + | - | - | + | + |
| | hydraulic gradient | - | - | + | + | + |
| | hydraulic conductivity | - | - | + | +/- | O |
| | water level depth | + | + | + | + | + |
| | aquifer thickness | + | + | + | + | + |
| | porosity/storage coefficient | O | O | + | O | + |
| | homogeneity/heterogeneity | - | - | + | - | + |
| | rock type (porous/fractured/karst) | - | - | + | O | + |
| quality | ambient groundwater salinity | + | +/- | +/- | +/- | + |
| | ambient groundwater quality | + | - | +/- | + | + |
| | aquifer matrix material (potential for geochemical interactions) | n.i.a. | n.i.a. | + | n.i.a. | + |
| | distance to pollution sources | + | - | +/- | + | + |
| economic | distance to source | - | - | + | - | + |
| | distance to user | + | + | + | - | + |
| | elevation differences | - | - | + | - | + |
| | available space/land prices | O | + | - | + | + |
| | preexisting infrastructure | + | + | + | - | + |

Table 1: Evaluation criteria for Managed Aquifer Recharge (+ = high suitability, - = low suitability, O = moderate suitability, n.i.a. = no information available)

was integrated over the area to assess the available storage that resulted from groundwater development. The criteria partially depend on each other, making it difficult to provide a simple, single metric. The criteria were for this reason not converted into an equation, since this would lead to a loss of information, especially considering different stakeholders having different objectives. The inventory thus provides a semi-quantitative overview of different aquifer systems and evaluates their respective suitability for short- and long-term storage of desalinated seawater.

## RESULTS

Table 1 gives a comprehensive summary of the results. While some aquifers show high storage potential, others are less suitable. The Coastal Aquifer and the Disi Aquifer have a considerable economic advantage, since they are located close to the production plants. Both aquifers also have favourable connectivity to demand centers. Due to the fossil nature of the Disi Aquifer, groundwater losses during MAR are much lower compared to those of the Coastal Aquifer.

In addition, the injection of desalinated water might be employed as hydraulic control to minimize seawater intrusion and, for the Disi Aquifer, to reduce salinization processes, both of which being related to an excessive drawdown of the groundwater level and the mobilization of brines. The Western Mountain Aquifer (WMA) shows great potential for short-term and even long-term storage, despite its karst aquifer characteristics. This is related to (1) discharge converging to a single spring, i.e., uncontrolled losses to the sea are low, (2) the aquifer being heavily exploited, and (3) the karst groundwater having good water quality. The above-mentioned characteristics are likely to ensure a high recovery efficiency. As the Eastern Mountain Aquifer (EMA) is part of the same geologic complex, but lacks the three advantages of its western counterpart, its suitability for MAR is considered low. The Azraq Aquifer is less suitable because of its low economic suitability. More details on the inventory can be found in (Truong et al., 2022).

## CONCLUSION

The inventory is supposed to serve as a first but comprehensive overview for researchers, stakeholders, and decision-makers. It will be supplemented by input from regional partners with some alluvial aquifers. The results show that several aquifers are suitable for MAR. The storage volume is high: just from overexploitation a volume of up to 1.1 billion cubic meters of water was created. The inventory was used to select suitable aquifers for further investigations using modeling techniques. Modelling is imperative for the design of a management plan and to assess the associated losses. The modeling approach is explained in more detail in [Regional Models of Large-Scale Storage of Desalinated Seawater, p. 66].

## MANAGED AQUIFER RECHARGE (MAR)

MAR makes use of natural aquifers for groundwater storage by usually using infiltration ponds or injection wells. Figure 1 shows the principle of MAR. The different recharge methods have their own requirements regarding aquifer characteristics and source water quality. As desalinated water usually fulfills all water quality requirements, the hydraulic properties of the aquifer as well as the native groundwater quality are from a technical point of view the main constraints for a successful MAR implementation.

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