



## Managed Aquifer Recharge in Spain

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Managed Aquifer Recharge or artificial recharge (there is not still consensus on terminology in Spain) has been applied intentionally, according to chronicles, since the 12<sup>th</sup> century on the South slopes of Sierra Nevada Mountains. MAR devices used for irrigation are called “*careos*” (Fernández-Escalante *et al.*, 2005) and some authors attribute their origin to the Muslim period whilst others state it was originally from the Roman era. Interestingly, they have many aspects in common with the Peruvian “*amunas*” of the pre-Columbian period.

In the early 1960’s a pioneering large diameter recharge well was constructed in Barcelona by the water supply company (Custodio, 1986) as a complementary source for urban supply, starting a new phase in the classical Integrated Water resources Management (IWRM) schemes in Spain.

By the late 1980’s well-documented use of infiltration wells in Daimiel National Park were underway for environmental restoration. These were to mitigate the serious impact of drought on the wetlands and related ecosystems and to decrease the risk of the aquifer provisionally declared over-exploited due to the high pumping rate for irrigation.

At the same time the Spanish Geological Survey (IGME) drilled a deep borehole in the bank of Esgueva River (Valladolid) to test deep infiltration and injection (De la Orden *et al.*, 2003). Also some infiltration ponds were built related to an iron ore mine in Granada, further broadening MAR applications.

In the 1990’s several projects were carried out, testing the feasibility of the different MAR types in different areas. A detailed description for most of these sites can be found in DINA-MAR, 2009 and <http://www.dina-mar.es/post/2010/04/29/documentacion-tecnicanoticias.aspx>.

In addition new investments were made in short duration R&D projects, with the big disadvantage that many of these were abandoned after the supporting funds finished.

Currently there are more than 32 different MAR projects scattered around Spain (figure 1), with diverse facilities and methods to enhance recharge. Most of these activities were promoted by agents such as the Spanish Ministry of Agriculture by means of Tragsa Group, the Spanish Geological Survey (IGME) and the Catalanian Water Authorities, broadening the historical uses.

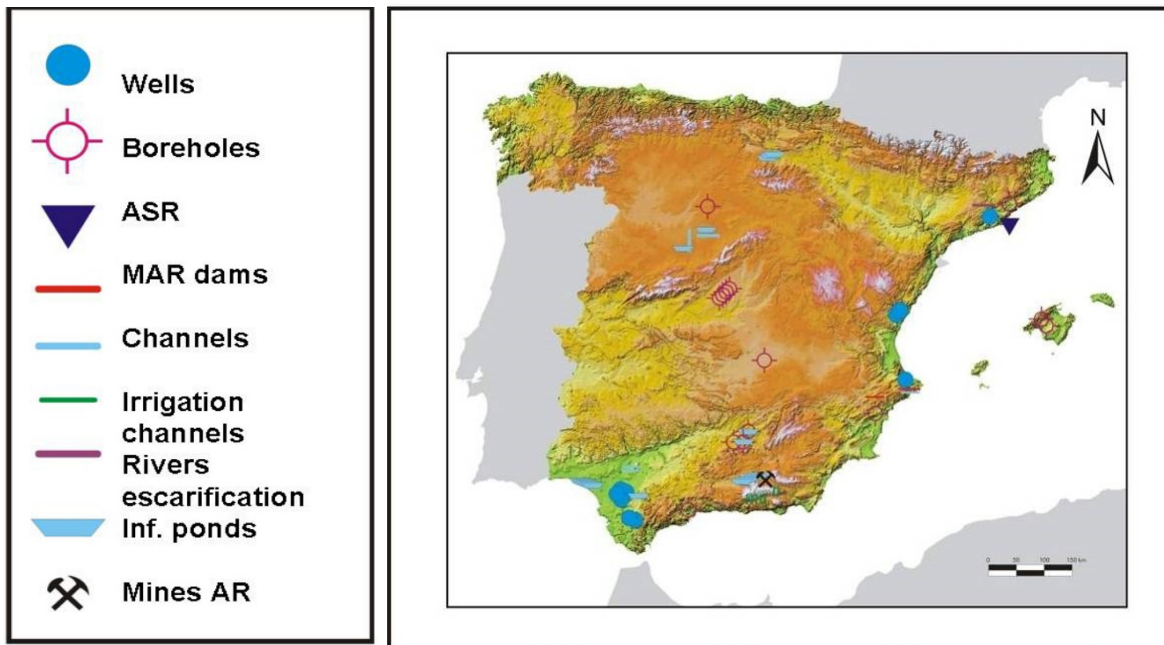


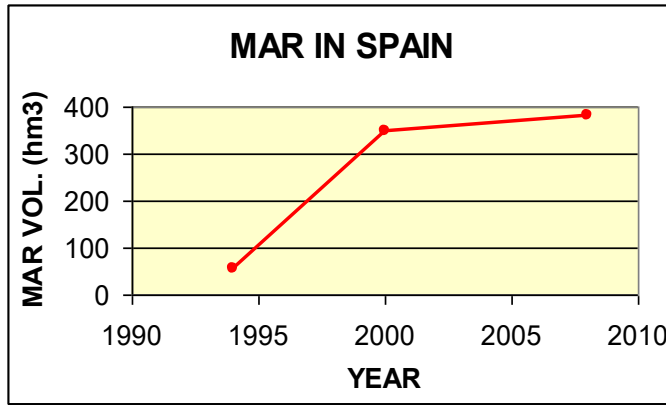
Figure 1. MAR facilities inventory in Spain, modified from DINA-MAR, 2009.

In general there are good examples of application for mining in the Southern area (Andalusia; Alquife; Cobre las Cruces). In the central area there are abundant canals and infiltration ponds for MAR. For example, starting in 2002, Los Arenales aquifer is the biggest large scale MAR area in Spain actively involving many agro-industries and becoming good examples of cooperation between farmers and researchers and Public-Private Partnerships (PPP). The deepest boreholes for ASR have been drilled in the big cities (Barcelona since 1969 and Madrid since 1995) so as to enhance reliability and increase supply of urban water. Along the Mediterranean Arc are many examples of detention structures such as dykes, check dams and dams to slow down the floods called “gotas frías” that are common in the Mediterranean area, diverting high flows to recharge aquifers.

According to Fernández (2018) the biggest volume of intentional recharge infiltrated into the aquifer is conducted by about one thousand dykes and dams constructed along the upper catchments of river basins, to reduce flash-floods and their devastating effects. Although these facilities (constructed by the Institute for the Nature Conservation, ICONA, since the 1950's) have multiple uses, they retain water and considerably enhance the natural recharge by about 200 Mm<sup>3</sup>/year.

Among all the examples reported, the vast majority were promoted by the public sector. Among the exceptional private initiatives it is worth mentioning those at Marbella and Majorca Island. The official estimate of the annual volume of water recharged via MAR in Spain has grown from 50 to 60 Mm<sup>3</sup>/y (LBAS, 1994) to 350 Mm<sup>3</sup>/y (LBAE, 2000).

In 2008 the total volume of MAR in Spain was about 380 Mm<sup>3</sup>/year (DINA-MAR; 2009). About three quarters of this was by means of these dykes and check dams in the upstream sections of the river basins, especially on the East coast. Some of these facilities were developed around the year 2000 for intentional recharge by institutions such as Diputación de Alicante.



(1994, LBAS)	<b>50-60</b>
(2000, LBAE)	<b>350</b>
(2008, DINA-MAR)	<b>380</b>

Figure 2. Artificial recharge of groundwater in Spain [ $10^6\text{m}^3/\text{year}$ ]

According to the catalogue of European MAR applications for 23 countries DEMEAU (2014) classified according to 10 different MAR types (Figure 3) the biggest number of sites are in the Netherlands and in Germany, and Spain is the country with the biggest diversity with 8 of the 10 different MAR types represented.

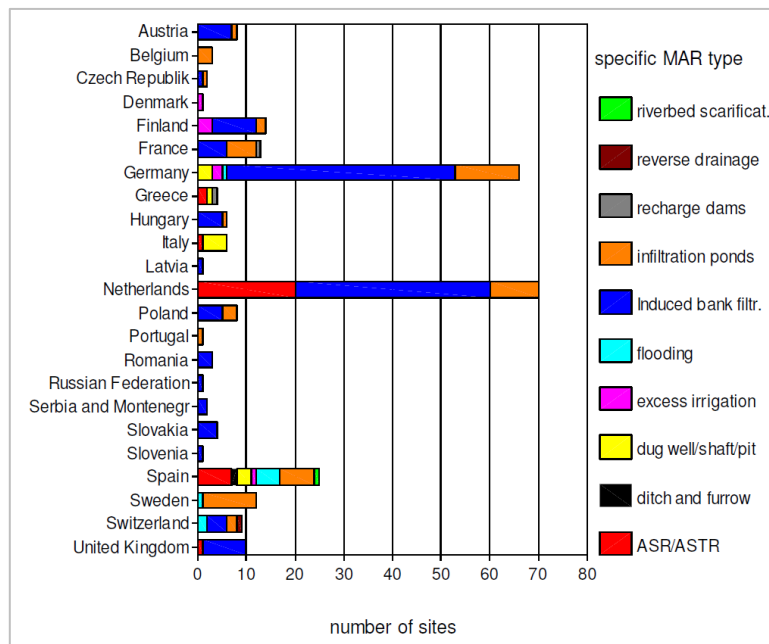


Figure 3. MAR sites vs MAR types for 24 European countries (DEMEAU, 2014).

A large number of MAR activities or demonstration sites using reclaimed water from waste water treatment plants (WWTP) have spread throughout Spain (Figure 4). Important experience is being gained in Costa Brava (e.g. Port de la Selva) and in Barcelona airport area, where saline water intrusion is inhibited by means of reclaimed water recharge in Llobregat river delta.

In summary, MAR has been present in Spain for several centuries and today there is a great variety of MAR facilities, that makes Spain an excellent country to visit to observe different working examples of most types of MAR. It is also worth mentioning there are more than 24 MAR facilities envisaged (especially for Ebro and Guadalquivir river Basins) in the second generation of Basin Plans, already published, which are commitments of the Spanish Government with their citizens and with the European Commission.

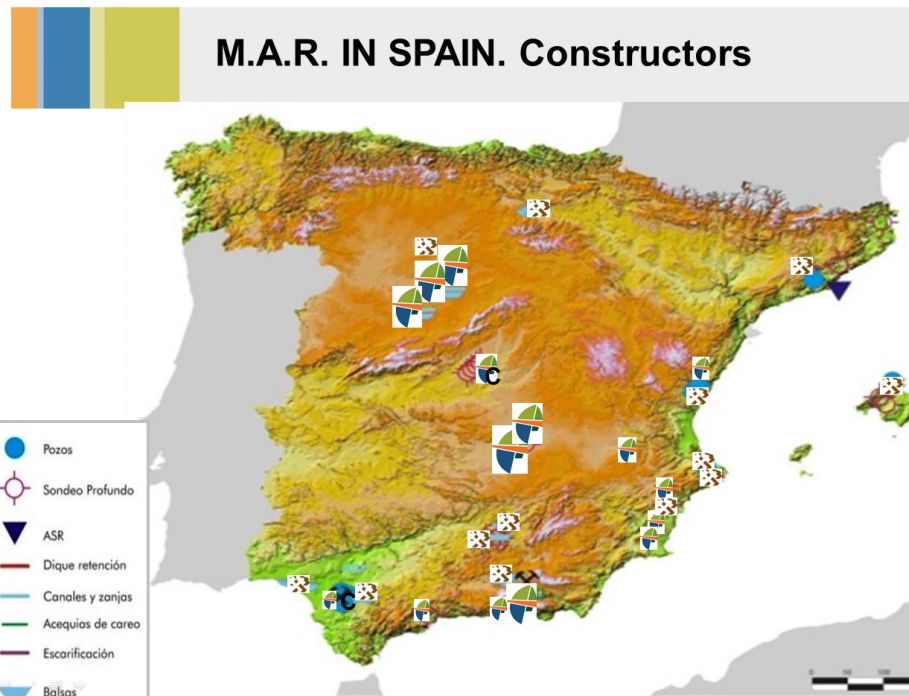


Figure 4. Map of MAR sites in Spain (DINA-MAR, 2009).

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