MARSOL

Demonstrating Managed Aquifer Recharge as a Solution to Water Scarcity and Drought

Managed Aquifer Recharge to Combat Groundwater Overexploitation at the Los Arenales Site, Castilla y León, Spain

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1. EXECUTIVE SUMMARY

This report is part of the MARSOL (www.marsol.eu) FP7-founded EU project (Grant Agreement Number 619120) and the last one of its Work Package 5 on the Los Arenales demonstration site in Spain.

The main objective of this deliverable is to report and evaluate the different components of a MAR system willing to combat groundwater over-exploitation, based on the experiences and new developments performed at Los Arenales demo-site. Some key environmental factors are specially considered, as the artificial wetlands and the profitable effect of MAR technique on them, the effect of enhanced recharge on ecosystems and, the most important, the tested effectiveness of MAR as a technique to palliate some climate change adverse impacts.

The “improved MAR techniques” accomplished at Los Arenales demo-site have demonstrate the potential of MAR to combat groundwater over-exploitation by discharging river water, by means of Waste Water Treatment Plants and runoff, in fulfilment of the objectives 1 and 2 of the 5th work package description (DoW, pg. 22). Public participation and educational activities directed at farmers and irrigation communities have had intense dedication, by means of two specific training workshops (objective 3). The objective 4 related to the potential of MAR to enhance economic resurgence in rural areas has also been studied in this deliverable, as well as objectives six and seven which targets are the Implementation of Public Private Partnership (PPP) schemes and to develop a Decision Support Systems (DSS), always from a practical and applied perspective.

According to the tasks stated in the description of work, there is a special dedication on conclusions from task operation (task 5.1) and on artificial wetlands and related environmental elements (task 5.5). Most of the aspects regarding solutions associated to environmental specific elements have been deployed in this deliverable in three consecutive stages: *technical (including environmental), economical and legal aspects*.

With this deliverable all the objectives and tasks envisaged in DoW have been fully covered, pending the inputs for modelling solutions.

After this brief summary and the introductory paragraph, section three focusses on MAR environmental associated elements, loaning a detailed dedication on water quantity and quality aspects correlated to purifying elements such as the “triplet” scheme, biofilters, artificial wetlands and WWTP improved designs. Also the actual usefulness of MAR to combat groundwater over-exploitation by means of water diverted from a river and from a WWTP.

Section four pays special dedication to rural development, studying the agroindustry development in all the municipalities affected by MAR activities across the three areas of study (Santiuste basin, El Carracillo council and Alcazarén area).

Section five provides some examples of Public Private Partnership (PPP) schemes, relations with water authorities and water and energy suppliers. This section includes some examples for Dissemination and Technology Transfer (D&TT) activities.

Section six explains how MAR is linked to Decision Support Systems (DSS) in this aquifer, in special regarding regulations and legal modifications as the MAR system progress in the area. Finally, consecutive chapters have been devoted to conclusive remarks, references and annexes.

2. INTRODUCTION

The MARSOL project aspires to provide scientists, practitioners and end-users with an engineering-enabled set of solutions to improve Managed Aquifer Recharge (M.A.R. or simply MAR) efficiency in areas where it is applied.

The principal problem faced by the Water Authorities in Los Arenales demo-site was the irrigation decreasing resource because of the intense pumping during several years, even decades, until Los Arenales aquifer was provisionally declared over-exploited (1995). In reaction, Managed Aquifer Recharge was the main technique adopted by the Spanish Ministry of Agriculture to combat this situation and to bring back the aquifer to preoperational conditions, in order to avoid jeopardizing the rural development in the area.

This specific deliverable intends to collect all the risks and impacts which drove to an over-exploitation situation and the measures sought and applied within three different groups, technical (including environmental), economical and socioeconomic (in relation to rural development) and legal [including Decision Support Systems (DSS) and Public Private Partnership (PPP) mechanisms].

MARSOL has built a bi-directional communication channel between technicians and end-users, in general farmers grouped in irrigation communities, enhancing the social participation as a key source of inspiration and a real source of information to accomplish useful activities driving to useful outcomes.

This report firstly introduces an overexploitation definition (chapter 3), including lists of impacts and consequences embedded in the aquifer over-exploitation term, *sensu lato;* and in Los Arenales demo-site *sensu stricto*.

Chapter 4 presents a general description of the area regarding groundwater abstraction and recharge in the three plants considered along the project (Santiuste basin, El Carracillo Council and Alcazarén area).

Chapter 5 describes the main MAR-based solutions performed to combat the aquifer over-exploitation at Los Arenales from a technical perspective.

Chapter 6 focus on MAR as a technique for rural development and minimize aquifer over-exploitation risk, taking into consideration some economic aspects.

Chapter 7 provides some examples for PPP schemes, explaining some site selection methodologies for MAR, evolution of the regulation and interaction between irrigation communities and the river basin authority. Other PPP considered have been the relations with water and energy suppliers and how the water and energy efficiency improvements are playing an important role to avoid undesirable situations regarding groundwater storage.

Chapter 8 studies the relation between MAR and DSS, describing the changes that have taken place in the organizational structure along the period since MAR activity began.

Finally, some conclusive remarks, references and annexes are shown to complement the previously exposed information.

3. OVER-EXPLOITATION: BACKGROUND AND CONSEQUENCES

Overexploitation may be defined as the situation in which, for some years, average aquifer abstraction rate is greater than, or close to, the average recharge rate. But rate and extent of recharge areas are often very uncertain. Besides, they may be modified by human activities and aquifer development. In practice, however, an aquifer is often considered as overexploited when some persistent negative of features are felt or perceived into the aquifer, such as a continuous water-level drawdown, progressive water-quality deterioration, increase of abstraction cost or ecological damage. But negative results do not necessarily imply that abstraction is greater than recharge. They may be simply due to well interferences and the long transient period that follow changes in the aquifer water balance (Custodio, 2002).

Groundwater sustainability is understood, in accordance with the definition given by circular 1186 published by the United States Geological Service [Sustainability of 20 Ground-Water Resources, USGS, 1998, in Rodríguez-Estrella, T. (2012)] as "the development and use of groundwater in a manner that can be maintained for an indefinite time without causing unacceptable environmental, economic or social consequences". In order to achieve a sustainable management of groundwater, the USGS proposes the following strategies:

- Use sources of water other than local groundwater, for example, importing surface water from outside river catchments that are in surplus
- Change rates or spatial patterns of groundwater pumping
- Increase recharge to the groundwater system
- Decrease discharge from the groundwater system
- Change the volume of groundwater in storage at different time scales.

The main impacts and consequences (both, direct and indirect) from aquifer over-exploitation, according to Wikipedia, 2016, are:

Direct consequences:

- Water table decline in the affected area
- Terrain compacting
- Aquifer partitioning
- Exploitation costs increase
- Water quality deterioration
- Abandonment of wells
- River-aquifer relation modifications
- Changes induced by the regime of the river and its modifications
- Affection or drying of wetlands
- Legal problems due to third parties´ rights affection.

Indirect consequences:

- Problems in drainage networks and infrastructure breaks
- Soils salinization
- Progressive desertification
- Geotechnical problems such as subsidence and collapses
- Modifications in the physical properties in the aquifers
- Affection from large distance contamination processes.

3.1 Aquifer over-exploitation at Los Arenales demo-site

First of all it is important to clarify that Los Arenales limits have changed in accordance to the legal distribution of water bodies in Spain. It was firstly the name applied for a multi-province aquifer; in the eighties the aquifers received the name of “hydrogeological units”, term which included some legal and management connotation. After the Water Framework Directive 2000/60/CE (WFD) was published, groundwater units were redistributed again, receiving the name of “masas de agua” (water bodies), and the initial surface of the aquifer was dramatically reduced.

Currently, Los Arenales Water body has a surface of 7,754 km^2, including 96 villages in Valladolid, Segovia and Ávila provinces, sheltering 46,000 inhabitants. It is an area where the main ***driving force*** of the local economy has been and still is the **agriculture**.

Since 1972 groundwater extraction in the water body 020.045, Los Arenales (according to the most modern distribution and terminology) increased, and the groundwater table registered a progressive decline, quantified up to 27 m between 1972 and 2002 (figure 3-1). In this period some other aquifers in Spain registered parallel situations (e.g. Mancha Occidental, Utiel-Requena), due to the fact that rural development was depending on irrigation agriculture and this relied on groundwater extraction.

In this situation, there was a great environmental deterioration, therefore, most of the impacts and consequences of over-exploitation exposed in the previous paragraph affected to the vast majority of the aquifer.

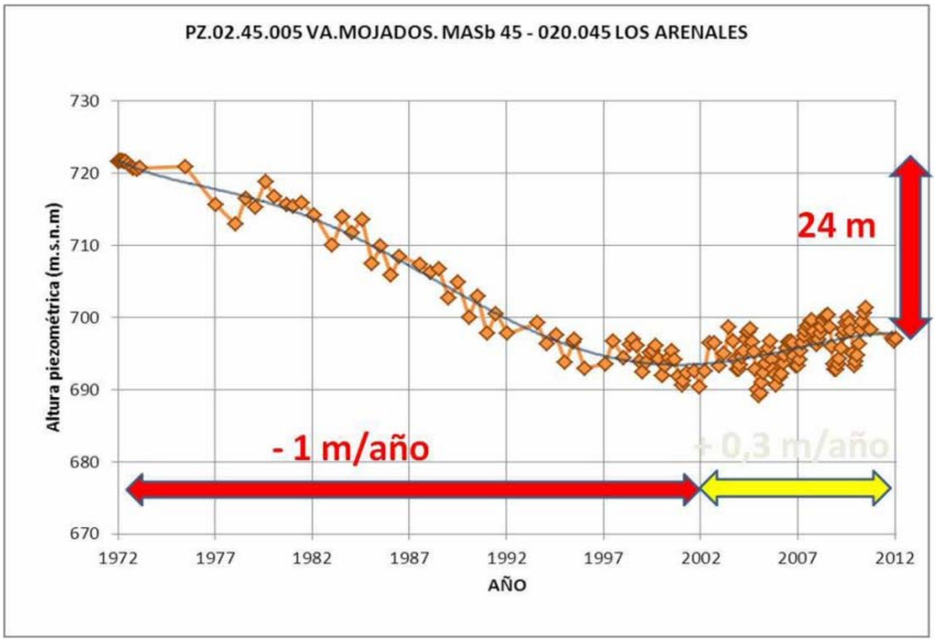


Figure 3-1: Groundwater level evolution at Los Arenales water-body (Del Barrio, 2014). Between 1972 and 2002 was registered a 27 m decline and a reaction by means of MAR, with a current accumulated decrease of 24 m for the whole aquifer.

By the end of the nineties and according to Spanish regulations [the Art. 81 of the Water Act (TRLA), became compulsory to organize communities of users *"water users and other goods”* in overexploited aquifers to establish internal rules related to groundwater governance.

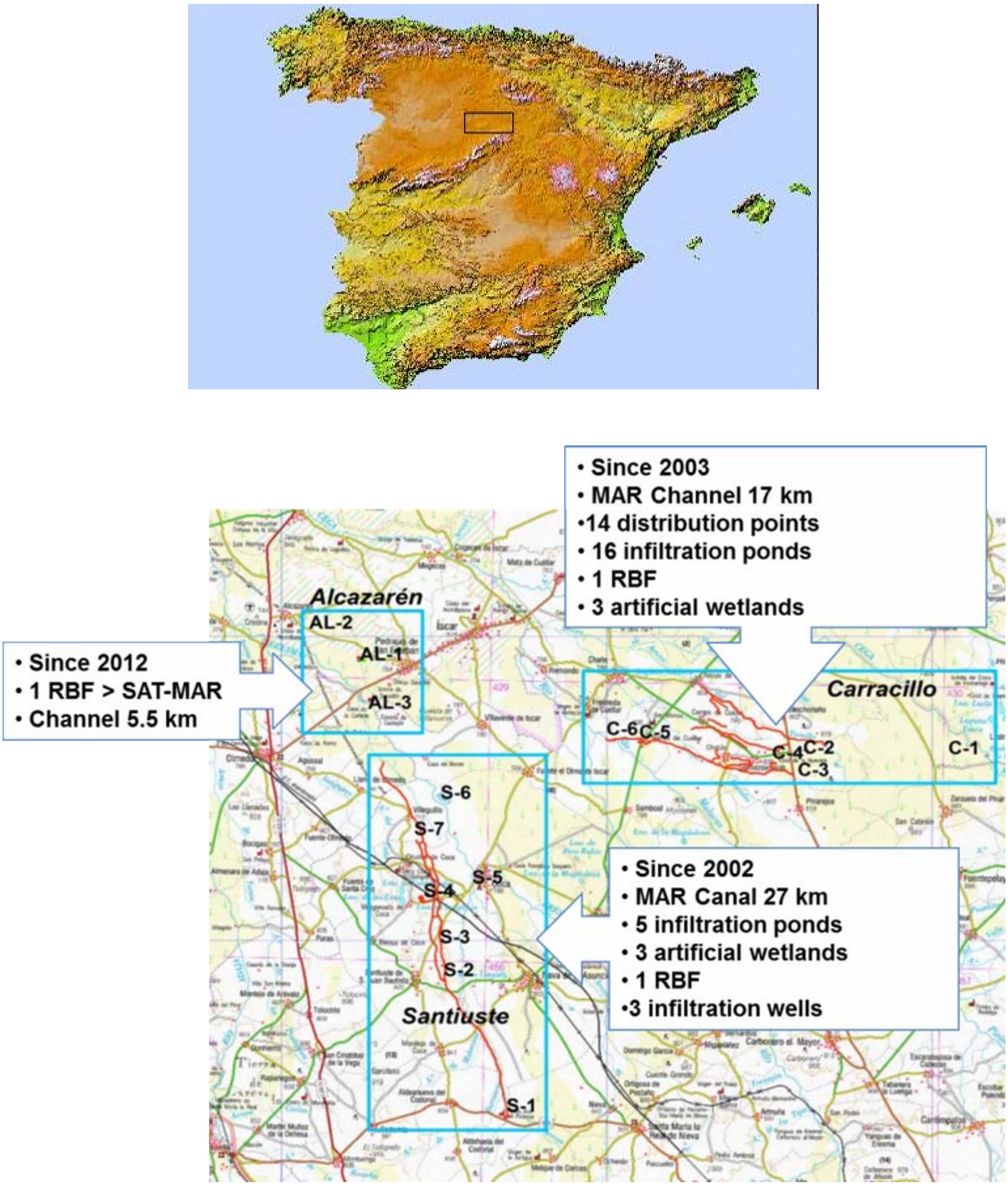
Prior 1998 the recent irrigation communities presented an official complaint and asked for a solution to their parliament member for Segovia province (Ms. Loyola de Palacio). The

Spanish Ministry of Agriculture (MAPA, nowadays MAPAMA) reacted accordingly, considering Managed Aquifer Recharge a technique to reverse this worrying impact. The context prompted the publication of the *Decreto-Ley 9/1998,* which considered some works for the recharge of the aquifer beneath **Santiuste** and El **Carracillo** areas, both inside Los Arenales aquifer. Both projects were branded as *"**National Common Goods**"* and the investment was justified as *"environmental costs"*, in order to test to what extent MAR activity was able to solve the over-exploitation situation. In **2002** Managed Aquifer Recharge activities began in the mentioned sectors of *Los Arenales*, entrusting the monitoring and new extensions to Tragsa Group, with the mandate to check permanently the aquifer response to MAR activities and to make an appraisal about how well the selected measure behaves.

Despite MAR is providing the expected results in these areas, which can be considered isolated, the still intensive exploitation of groundwater for the whole aquifer has an exploitation index (E_i) of 1.3 for the whole water body (Del Barrio, 2014). New intentional aquifer recharge experiences should be conducted in new areas of Los Arenales to bring this index down to below one unit. Nevertheless, there is an obvious lack of control of water extractions in the basin if these measures of recharge must be increased to recover groundwater table.

4. APPRAISAL OF THE RECHARGE IN THE PLANTS WHERE M.A.R. ACTIVITIES ARE PRACTISED WITHIN LOS ARENALES AQUIFER

A detailed description of the main MAR plants at Los Arenales aquifer have already been exposed in previous deliverables (see MARSOL 2015 a & b and 2016). The position of Los Arenales Aquifer in Spain and schemes with the main MAR facilities and their components are exposed in the Figures 4-1. It is advisable to consult the mentioned references by interested readers to achieve a better understanding of the aquifer and in order to avoid repetitions.



Figures 4-1: Los Arenales aquifer MAR systems position and devise of the facilities on the topographic map with a list of the main MAR components. Approximate scale: 1:150.000 (MARSOL, 2016).

Once the exploitation index was officially valued (E_i = 1.3), this paragraph exposes the most relevant technical figures related to the aquifer over-exploitation in Santiuste basin and El Carracillo District and the behaviour of the aquifer after MAR took place regarding volumes of water stored underground, operation times, infiltration rates, etc. The topologic schemes for the main plants are also included in this chapter.

4.1 Santiuste basin

The sketch in figure 4-2 contains the junctions and all the interconnected elements in the MAR plant of Santiuste. The most remarkable characteristics are:

- River water source: Voltoya River surplus.
- Maximum flow: 1,000 litres per second from November 1st to April 30th, as far as the outflow is measured in the own river.
- Annual maximum volume allowed diversion (irrigation use): 8,020,000 m^3.

More detailed data and calculated figures are displayed in table 6-11.

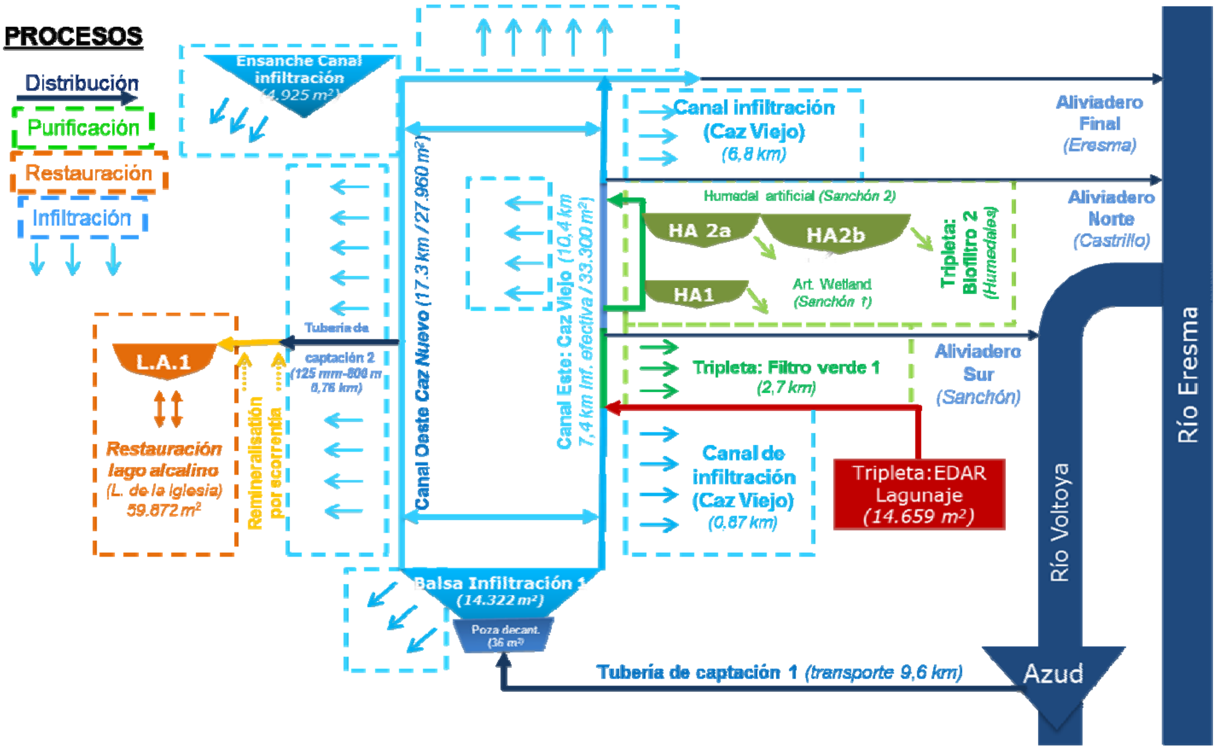


Figure 4-2: Operational sketch of Santiuste basin, the pioneer MAR plant at Los Arenales aquifer.

VOLUME DIVERTED FROM VOLTOYA RIVER FOR MAR.

The whole bulk of water diverted from the source can be expressed in a total accumulated volume through the operation years. The accumulated total amount has been 45.55 hm^3 during the last 14 years, even though there was a non-operational campaign in 2011-2012 because of the dry character of the winter season.

Table 4-1: Total diverted water volume from Voltoya River in Santiuste MAR demo-site (Los Arenales, Spain).

Recharging campaign	Total diverted volume (hm^3/campaign)	% of the highest authorized diversion volume (8.5 hm^3)
2002/2003	3.5	41%
2003/2004	2.25	26%
2004/2005	1.26	15%
2005/2006	5.11	60%
2006/2007	12.68*	149%*
2007/2008	0.52	6%
2008/2009	3.87	46%
2009/2010	0.7	8%
2010/2011	3.13	37%
2011/2012	0	0%
2012/2013	3.48	41%
2013/2014	2.04	24%
2014/2015	3.58	42%
2015/2016	3.43	40%
Total (14 campaigns in 15 years)	**45.55**	**39-41% (average)**

** This recharge exceeded the annual maximum diversion volume of 8.5 hm^3 established by the Water Authority permission so Irrigators Community was fined.*

In order to compare this feature to other sites that have not been working for such a long period, it would be possible to use a comparable parameter as an average diverted volume per year, so, the record for Santiuste would be 3.24 hm^3/cycle (taking into account 13 years of activity) or 3.51 hm^3/cycle, in case the no-recharging cycle (2011-12) were removed from the calculation.

Another way to measure the effect of MAR in the target aquifer could be the adoption of a parameter that reflects the impact on the yearly water basin availability; for instance, the percentage of water flow in the donating source (river) that is diverted for recharge. In the case of Santiuste, the way to assess that pressure on the donor river has been done using the highest permitted volume (8.3 hm^3) as a reference (second column in table 4-1). So, it gets an average of 38-41% of the total potential diversion (depending on the number of recounted cycles, i.e. with or without zero diversion volume).

OPERATION TIME

Another elementary figure obtained for the demo-site is the time the recharge has been working every season, or at least, the period of time when the water diversion was taking place as infiltration can sometimes last longer.

In Santiuste basin the operation time is more than 100 days per year as an average, but seasons are extremely irregular and there have been campaigns as short as a single week (2007/08) and as long as 212 days (twice: 2004/05 and 2006/07). Total Potential time duration is limited by the Water Authority permission that extends from November 1st to March 31th (182 days per year unless leap years). Average recharge has consumed just a 59% of total potential time since it began in 2002. That irregularity is a sign of the times as *Climate Change* forecast indicate the decreasing availability of running water from mountain Rivers during winter, and the serendipity of a seasonal water surplus.

Table 4-2: Operational time of Santiuste MAR demo-site (Los Arenales, Spain) per campaign.

Recharging campaign	Operational time (Days)	Operational time (hours)	% Maximum operation time
2002/2003	145	3480	80%
2003/2004	175	4200	96%
2004/2005	**212**	**5088**	**116%***
2005/2006	137	3288	75%
2006/2007	**212**	**5088**	**116%***
2007/2008	7	168	4%
2008/2009	181	4344	99%
2009/2010	43	1032	24%
2010/2011	68	1632	37%
2011/2012	0	0	0%
2012/2013	76	1824	42%
2013/2014	57	1368	31%
2014/2015	76	1824	42%
2015/2016	61	1464	32%
Total (14 cycles in 15 years)	**1450**	**34800**	**47%**
Average/year	**103.57**	**2485.71**	**57%**
Average/operational campaign	**111.53**	**2485.71**	**61.28%**

** These recharges exceeded the annual maximum diversion time of 182 days established in the Water Authority permission.*

DIVERSION RATE

The diversion rate could be expressed as a constant outflow measured in a flowmeter, but the most important datum is the final volume arriving to the MAR facilities, so that, figures are collected either from various seasons or from different allocations. All of that makes any comparison difficult to achieve.

Table 4-3: Diversion rate of Santiuste MAR demo-site (Los Arenales, Spain) per campaign.

Recharging campaign	Diversion rate (m^3/h)	Diversion rate (L/s)	Diversion rate (% of maximum capacity)
2002/2003	1,005.75	279.37	28%
2003/2004	535.71	148.81	15%
2004/2005	247.64	68.79	69%
2005/2006	1,554.14	431.70	43%
2006/2007	2,492.14	692.26	69%
2007/2008	**3,095.24**	**859.79**	**86%**
2008/2009	890.88	247.47	25%
2009/2010	678.29	188.42	19%
2010/2011	1,917.89	532.75	53%
2011/2012	0	0	0
2012/2013	1,907.89	529.97	53%
2013/2014	1,491.23	414.23	41%
2014/2015	1,962.72	545.20	55%
2015/2016	2,344.95	651.37	65%
Average/operational campaign	**1,437.46**	**399.30**	**44%**

Though the diversion should be proportional to the time the pipe is taking in water, the 2007-2008 cycle happened to be the most successful campaign in Santiuste (86% of diversion conducted) when the bypass rate reached up to 3,095 m^3/hour. That scores 859.79 L/s, from a maximum pipe capacity of 1,000 L/s, with a final average of 411 litres per second or 41% rate, the highest value for Santiuste MAR system since it began working.

INTENTIONAL RECHARGE RATE

Finally, the most relevant data came from the recharge rate; figure which is considered the most important goal for any MAR mechanism: “*to recharge as much water as fast as possible*”. Considering the total amount of water infiltrated into the aquifer, the winter of 2006-2007 was really successful with more than 12 hm^3 added to Los Arenales aquifer storage (96% percentage), but considering the ratio between diverted and penetrated water, the best result was obtained in the cycle 2013/2014, with just 2 hm^3 subverted, but at full capacity (98% effectivity) and only a 2% loss through the MAR facilities from the capture to the seepage plots.

Table 4-4: Infiltration rate of Santiuste MAR demo-site (Los Arenales, Spain) per campaign (except 2015/2016 ratio*).

Recharging campaign	Infiltrated volume (hm^3/year)	Infiltration rate (% Inf/Div)
2002/2003	1.3	37.14%
2003/2004	1.8	80.00%
2004/2005	0.97	76.98%
2005/2006	3.56	69.67%
2006/2007	**12.19**	**96.14%**
2007/2008	0.46	88.46%
2008/2009	2.5	64.60%
2009/2010	0.64	91.43%
2010/2011	2.13	68.05%
2011/2012	0	0.00%
2012/2013	3.25	93.39%
2013/2014	**2**	**98.04%**
2014/2015	3.18	88.83%
2015/2016	3.43	n/a
Average/year	**2.67**	**73.29%***
Average/operational cycle	**2.88**	**79.39%***

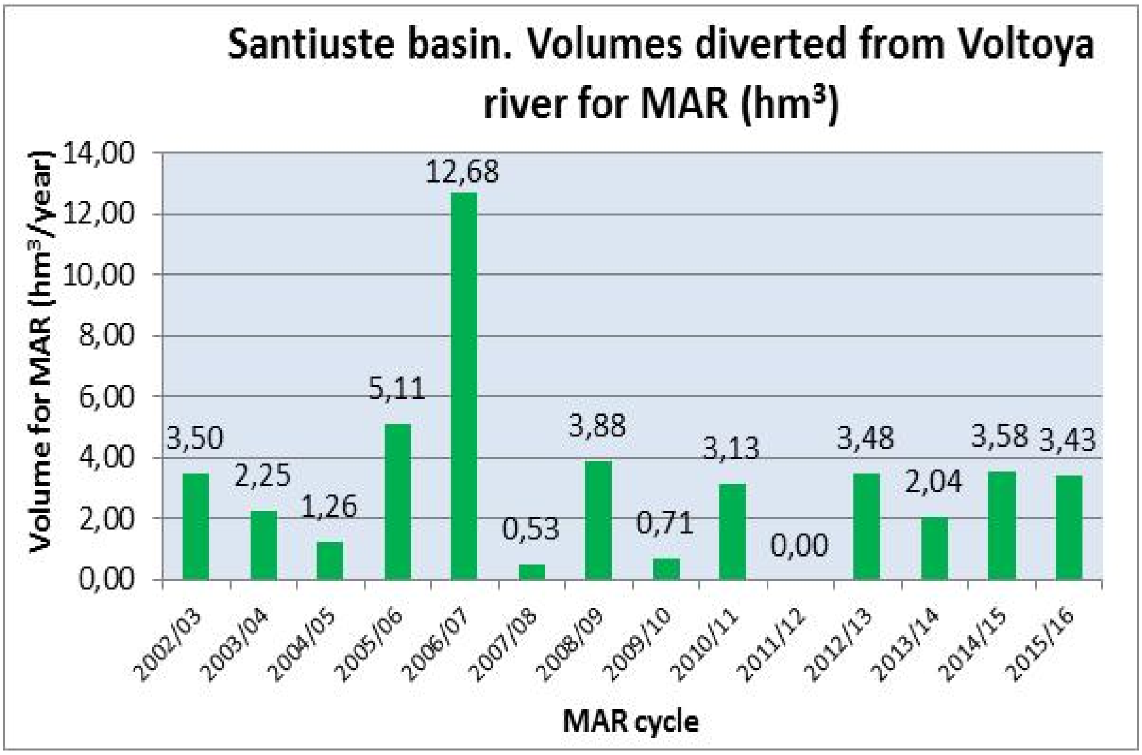


Figure 4-3: Diverted volume *versus* recharged volume at Santiuste Basin, period 2002-2016.

4.2 El Carracillo District

Figure 4-4 contains a general sketch with the junctions and all the interconnected components in the MAR set of Santiuste basin. The most remarkable characteristics are:

- River water source: Cega River surplus
- Maximum flow: 1,370 litres per second (L/s) from January 1st to April 30th as far as this same outflow is measured in the river
- Annual maximum volume (irrigation use): 14.2 hm^3
- Recharge amount: 32,68 hm^3 (14 years)
- Water processed by MAR facility (unitary): 24.18 m^3/ha·in 14 years
- River basin civil servants supervise the gate to divert water from Cega river, managed by the irrigation community
- There is an specific permitted period and it is revisable yearly
- An environmental minimum flow rate must be respected: 6,898 L/s (initial permission)
- Maximum diversion: 1,370 L/s from January to April (2nd revised permission)
- The total flow rate minor than 22,4 hm^3/year
- Flow meter controlled in real time by legal requirement, being useful for analyses and studies.

More detailed data are displayed in table 6-11.

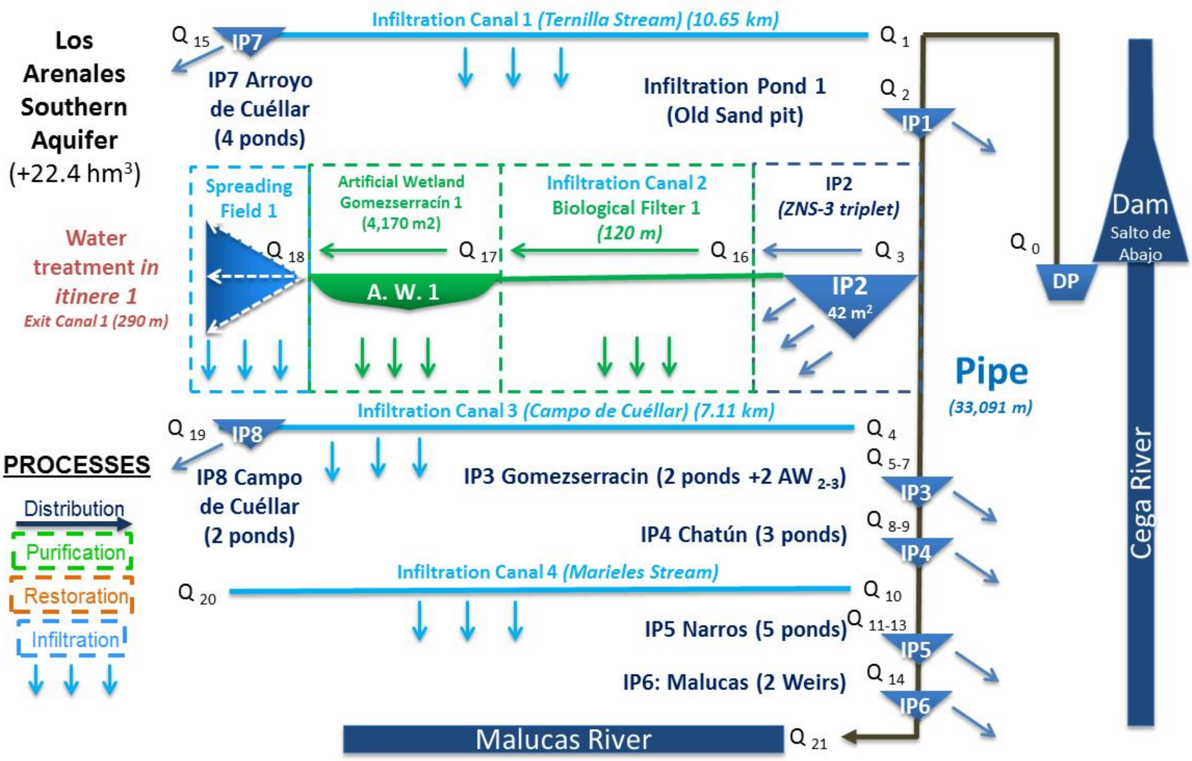


Figure 4-4: Operational sketch of El Carracillo MAR plant. The *triplet* is situated at IP3.

VOLUME DIVERTED FROM CEGA RIVER FOR M.A.R.

During the last 13 years a total volume of 42.12 hm^3 has been diverted from Cega River, even though there were two non-operational rounds in 2004-2005 and 2007-2008 due to rainfall deficit during those years.

Table 4-5: Total diverted water volume from Cega River in El Carracillo MAR demo-site (Los Arenales, Spain). In 2002* diversion was zero.

Recharging campaign	Total diverted volume (hm^3/campaign)	% of the highest authorized diversion volume (14.2 hm^3)
2002/2003*	0.5	3,52
2003/2004	5.5	38,73
2004/2005	0.0	0,00
2005/2006	1.85	13,03
2006/2007	2.1	14,79
2007/2008	0.0	0,00
2008/2009	1.6	11,27
2009/2010	5.61	39,51
2010/2011	2.98	20,99
2011/2012	1.91	13,45
2012/2013	7.18	50,56
2013/2014	1.64	11,55
2014/2015	0.25	1,76
2015/2016	1.56	10,99
Total (12 cycles in 15 years)	**32.68**	**16,44% (average)**

OPERATION TIME

In El Carracillo council, the average operation duration is approximately 90 days per year (93.76 days) but, as it happens in Santiuste basin, the working period is extremely irregular, since 27 days in 2015 to 149 days at the beginning of the MAR scheme (2003, 2004, 2006, 2007 and 2009). Average recharge has consumed a 71.5% of total potential time since it began in 2002. It is worth mentioning that in 2009 the River Basin Authorities (CHD) approved a modification extending the set-up time to 5 months (from December 1st to April 31th). However, in 2013 this modification was annulled, returning to the original operation period.

Table 4-6: Operational time of El Carracillo MAR demo-site (Los Arenales, Spain) per campaign.

Recharging campaign	Operational time (Days)	Operational time (hours)	% Maximum operational time (90 days averaged)
2002/2003	149	3576	124%*
2003/2004	149	3576	124%*
2004/2005	**0**	0	0%
2005/2006	149	3576	124%*
2006/2007	149	3576	124%*
2007/2008	**0**	0	0%
2008/2009*	149	3576	99%
2009/2010*	89	2136	59%
2010/2011*	90	2160	60%
2011/2012*	60	1440	40%
2012/2013*	119	2856	79%
2013/2014	89	2136	74%
2014/2015	27	648	23%
2015/2016	59	1416	66%
Total (12 campaigns in 15 years)	**1219**	**29256**	**-**
Average/year	**87.07**	**2089.71**	**-**
Average/operational campaign	**101.58**	**2438.00**	**62.50%**

** MAR operated during these years under the modification of the established Concession (5 months).*

DIVERSION RATE

The maximum flow-rate permitted to be distracted from Cega River is 1,370 L/s, ensuring a minimum downstream flow of 6,989 L/s. The 2012-2013 term happened to be the most successful campaign in El Carracillo (51% of rerouting rights) when the detour rate rose up to 2,514.71 m^3/hour, what represents 698.52 L/s.

Table 4-7: Diversion rate of El Carracillo MAR demo-site (Los Arenales, Spain) per campaign.

Recharging campaign	Diversion rate (m^3/h)	Diversion rate (L/s)	Diversion rate (% of maximum concession)
2002/2003	139.82	38.83	3%
2003/2004	1,538.03	427.23	31%
2004/2005	0	0	0
2005/2006	517.33	143.7	10%
2006/2007	587.24	163.12	12%
2007/2008	0	0	0
2008/2009	447.42	124.28	9%
2009/2010	2,411.99	669.99	49%
2010/2011	1,381.02	383.61	28%
2011/2012	1,327.78	368.82	27%
2012/2013	**2,514.71**	**698.52**	**51%**
2013/2014	836.14	232.26	17%
2014/2015	922.84	256.34	18%
2015/2016	1,063.96	295.54	22%
Average/operational campaign	**977.72**	**271,59**	**20%**

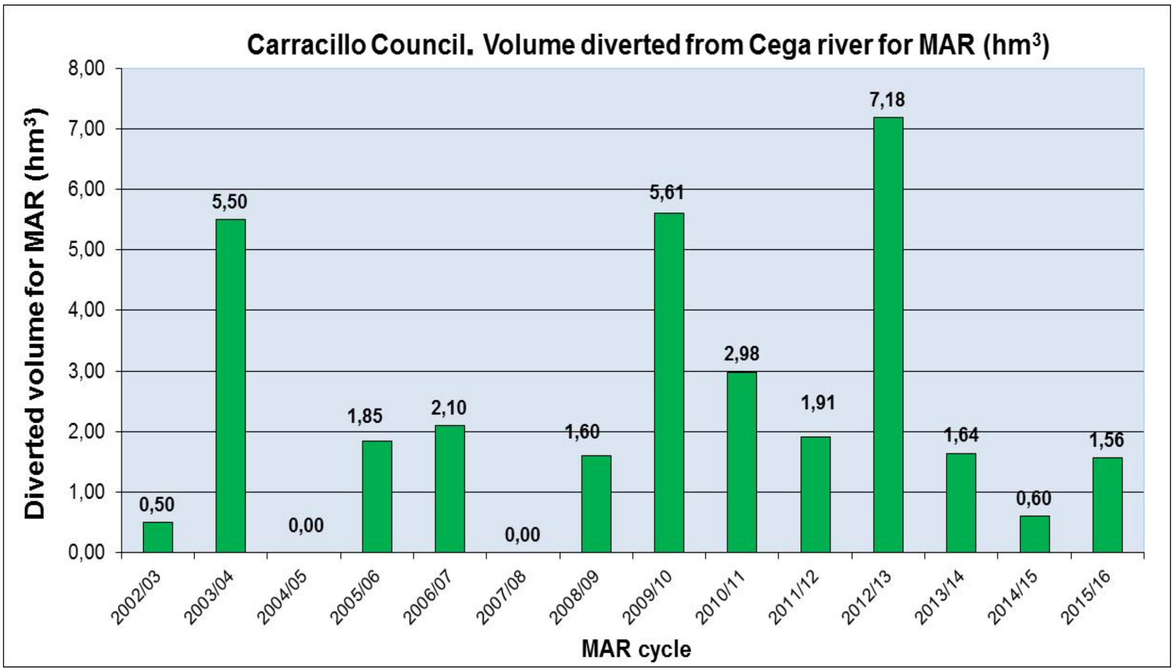


Figure 4-5: Diverted volume from Cega River (hm^3) in El Carracillo Council.

5. MAR AS A SOLUTION TO OVER-EXPLOITATION AT LOS ARENALES AQUIFER

As it has been exposed in previous chapters, the final bet to alleviate aquifer over-exploitation at Los Arenales is based on the Managed Aquifer Recharge (MAR) technique, considering technical (including environmental), socio-economical and legal aspects.

5.1 MAR-based solutions performed to combat the aquifer over-exploitation at Los Arenales

Regarding the technical scope, some specific applications of MAR have been either adopted or developed in this aquifer, achieving some solutions and proposal to be developed and applied in other scenarios. The main key elements developed have been:

- Diversification of sources at Los Arenales to increase the water supply guarantee
- Impacts and solutions related to the deviation of water from the river
- Impacts and solutions related to the use of water from a WWTP for MAR.

5.1.1 Diversification of sources to increase the water supply guarantee at Los Arenales

After 14 years of MAR activity at Los Arenales aquifer, the most accepted tendency based on empirical aspects relies on the diversification of water sources to assure a high water supply guarantee.

Initially all the MAR facilities were working with water rerouted from a river, and its effectiveness was dependent on extra flow rates or surpluses to be diverted.

By 2005 the reclaimed water proceeding from Santiuste WWTP was conducted to the MAR plant. This fact represented a 24 hours-7 days guarantee, with a greater availability in rainy seasons, but whose activity did not stop during the dry season. The average volume proceeding from the WWTP is about 5% out of the total.

The device does not require any energy costs (passive system). There is a difference of 17.81 meters between 815.37 m.a.s.l. in Voltoya Dam pipe inlet and 797.56 m.a.s.l. in Santiuste Infiltration Reservoir outlet, steep enough to avoid any energy cost by pumping.

The most modern MAR system, Alcazarén, has a novelty with respect to previous experiences and that is the water intake diversification, proceeding from 3 different sources: a river diversion from Pirón River, a WWTP with advanced secondary treatment and a ditch to drive runoff from the village roof tops to a connection point where MAR canal starts. This complex mechanism based on the variation of water sources has allowed a longer continuity of the system, recharging water not only from winter surpluses and consequently avoiding a reliance on river concessions for MAR.

It is important to foresee potential environmental aspects in the project stage prior implementing any construction. The problem/solutions binomials tendered in annex I may be useful for any impacts assessment evaluation.

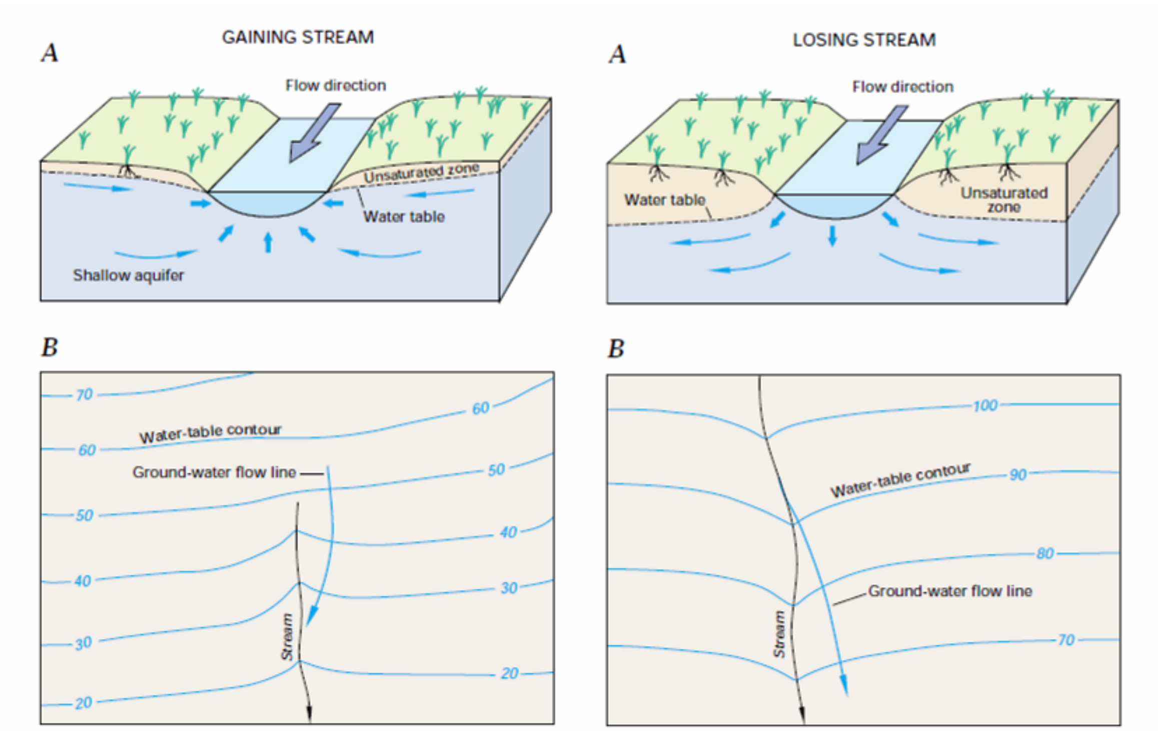
5.1.2 Impacts and solutions related to the diversion of water from the river

Traditionally, management of water resources has been focused on surface water or groundwater as if they were separate entities. But it is widely known that both water systems interact among them in a delicate balance. A withdrawal of water from streams can deplete groundwater resources or, conversely, groundwater pumping can lessen water flow in streams or other surface water bodies.

The main impact caused by the diversion of water from a river to combat aquifer overexploitation is the lower ecological flow-rate in the river (assuming that river water quality is acceptable for the recharge). It is therefore essential a complete understanding of groundwater and surface water interaction and the environmental consequences when we are planning a MAR project.

The interaction takes place in three basic ways:

- Streams gain water from inflow of ground water through the streambed (gaining stream) (figure 5-1 a).
- Flowing water becomes groundwater by outflow through the streambed (losing stream) (figure 5-1 b).
- Both, gaining in some stretches and losing in other stretches (Winter et al., 1998).



Figures 5-1 a) & b): Different river-aquifer relations (taken from Winter *et al*., 1998).

It is very important to clearly identify the input and output systems in the basin, in order to calculate the minimum necessary downstream flow after the recharge water intake. The ecological flow should guarantee the biodiversity of the river species, riparian vegetation and associated wetlands, among others. It also ensures the continuity of certain uses such as the downstream urban/industrial supply, hydro-electric power generation, etc.

It is essential to understand in detail the hydrogeological features and hydrodynamic characteristics of the environment and to obtain an accurate water balance of the aquifer sector to recharge.

In Los Arenales aquifer, the River Basin Authority (CHD) established a technical condition on a minimum downstream *"E-flow"* to determine the water diversion volume during the wet season, which varies between the different experiences carried out in this aquifer (exposed at chapter 7-1).

Figures 5-2: a) & b). Voltoya River in Santiuste Basin (a), and *Salto de Abajo* diversion dam in El Carracillo District (b).

5.1.3 Impacts and solutions related to the use of water from a WWTP for MAR

The previous deliverable 5-2 (MARSOL 2015a) indicates a vast amount of impacts affecting MAR areas. Special attention should be paid to one among the proposed solutions: it is the necessity of specific technical elements for rural areas where MAR activities are performed. The list of these key elements proposed to combat aquifer over-exploitation includes: improved WWTP with specific designs, adoption of combined structures such as "*triplet*" schemes to increase the self-purification capacity of the system, and the effectiveness of biofilters to treat water *in itinere*. These elements are described in the next section.

WWTP IMPROVED DESIGNS FOR RURAL AREAS

It Wastewater treatment by lagooning is usually considered a K technique and even a *soft method*, whose philosophy is based on several criteria such as low operating costs, reduced hand work, integration in the landscape from the ecological point of view, low maintenance costs, etc. These guidelines are relevant to relate reclaimed water to environmental improvements, including the struggle with aquifers over-exploitation.

The lagooning wastewater treatment system is based in a series of connected ponds called *"Waste or Wastewater Stabilization Ponds"* (WSPs). Depending on the number and characteristics of these reservoirs, the purification system varies and the result can either be depurated water (anaerobic lagoons + facultative lagoons) or reclaimed water (=treated wastewater) when an additional or complementary treatment is applied, e.g. one or several maturation ponds which help to bring up the quality until the intended use.

The implementation of a complete lagooning properly sized set according to the wastewater volume should provide an effluent good enough for environmental uses (under normal conditions).

The conventional sequence for a lagooning WWTP consists of anaerobic ponds + facultative ponds + maturation ponds (see figures 5-3 and 5-4).

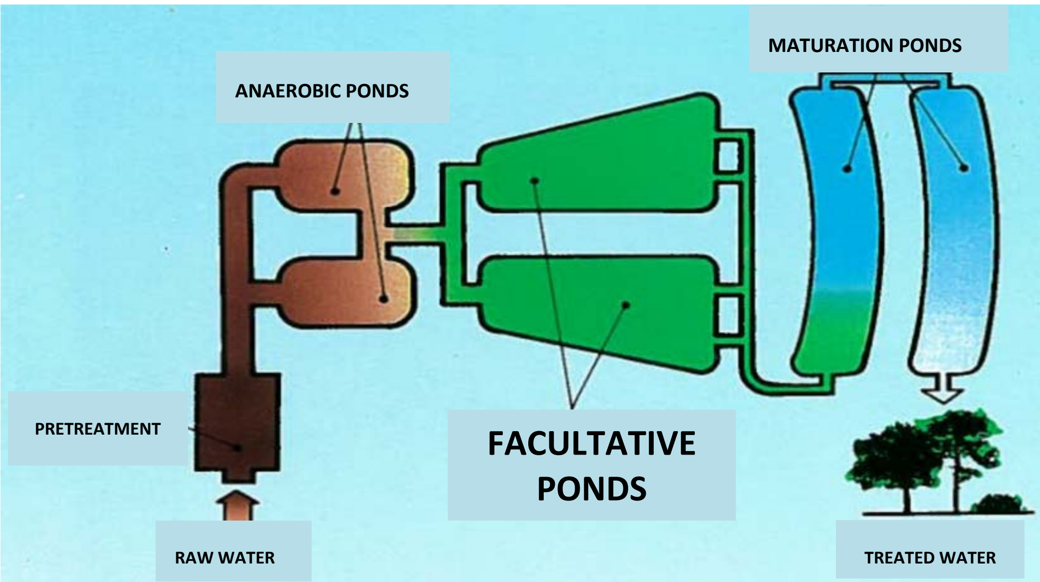


Figure 5-3: Most common scheme used in the natural lagooning.

Figures 5-4 a) & b): Real examples of natural lagooning plants in Castilla La Mancha (Spain) over an aquifer declared, provisionally, over-exploited.

Some of the main characteristics, operational parameters and designs recommended to improve a lagooning WWTP, either the aquifer beneath has been declared over-exploited or not, are the following:

1) ANAEROBIC PONDS:

- Operating conditions: calculus and design according to the retention time, volume and surface loads (Tables 5-1 and 5-2).

Table 5-1: Basic operational parameters (own elaboration).

BASIC OPERATIONAL PARAMETERS			
Surface organic load (Ls)	2,000	3,000	Kg BOD_5/ha*day
Volumetric load (Lv)	100	180	g BOD_5/m^3*day
Retention time (T)	2	5	days
Depth (m)	3	6	m

Table 5-2: Recommended values of volumetric load in anaerobic lagoons, depending on the design, temperature and the required quality yields (slightly modified from MARM, 2011).

Design temp (° C)	Volumetric load (Lv) (g BOD_5/m^3*day)	Removal of BOD_5 (%)
< 10	100	40
10 - 20	20T-100	2T + 20
20 - 25	10T + 100	2T + 20

2) FACULTATIVE PONDS:
- o Objective:
  - Stabilization of organic matter.
  - Reducing nutrient content.
- o Basis:
  - Symbioses of algae and bacteria.
  - Large surface for illumination and aeration.
- o Design parameters:
  - Multitude of methods according to the approach; complete mixing, dispersed flow, etc.
  - Basic calculation parameters depending on the surface organic load (Kg BOD_5/ha*day).

Table 5-3: Basic calculation parameters depending on the surface organic load (Ls) (own elaboration).

Surface organic load (Ls)* (Kg BOD_5/ha*day)	Climatic characteristics
< 10	Very cold areas with seasonal ice cover, water with low temperature and partly cloudy
10 - 50	Cold climate with seasonal ice cover and warm summer temperature in a short season
50 - 150	Between temperate and subtropical climate, occasional ice cover, without persistent cloudy conditions

** Organic surface loads above 300 BOD5/ha*day can be used in tropical climates.*

3) MATURATION PONDS:
- o Objective:
  - Reducing the content of pathogen bacteria.
  - Reducing nutrient content.
- o Pathogen removal process:
  - Physical: Decanting + Temperature.
  - Chemical: high pH for photosynthetic activity.
  - Shock O_2 concentrations.
  - Light intensity.
  - Low concentration of organic matter.
- o Design parameters:
  - Retention time > 5 days. Preferably > 7 days.
  - Minimum depth in order to favour illumination: 0.80 - 1.00 m.

"TRIPLET" SCHEMES PURIFICATION CAPACITY

This "SAT-MAR" structure is also a low cost system applicable in over-exploited aquifers and rural areas to improve the resulting water quality once water from different sources have been combined. A "triplet" is integrated by three consecutive elements (MARSOL, 2016): the pure SAT-MAR device where reclaimed water and run-off/river water are mixed, a green biofilter and a set of two or more consecutive artificial wetlands to finish the purification process. Later the water returns to the MAR canal with more optimum parameters for managed aquifer recharge. An environmental function, as landscape restoration or refuge for fauna, can be played at the same time that water treatment previous recharge happens.

In short, for the Santiuste case, the lagooning WWTP pours reclaimed water into the MAR canal, which conserves the natural vegetation in this stretch working as a green bio-filter (purification-environmental function); later it is re-directed to a set of artificial wetlands (environmental-purification function) and sent back to canal again (recharge). The main advantage is that water is treated *"in itinere"* while it is flowing through the infiltration channel by gravity.

1) First triplet element: WWTP by lagooning

It begins in the junction of the Lagooning WWTP "spill" with the MAR canal coming from the initial decantation pond at the heading of the structure.

The volume of reclaimed water in comparison to the MAR water in the canal is always below 5% during the recharge season. Then, there is an important initial dilution of the pollutants insufficiently purified (dilution as a solution to pollution), fulfilling all the required quality requisites according to the Spanish regulation RD 1,620/2007 (in BOE, 2007).

2) Second triplet element: Green biofilter

A stretch of 1,129 m of infiltration canal followed by another 1,577-meter-length section of semi-impermeable ditch connects the WWTP outflow with the artificial wetlands (the whole infiltration canal has more than 25 km length).

The biofilter plays a double role: on the one hand, the natural plants perform an important purifying activity on the potential pollutants which could have remained after the irregular water treatment process, even by single absorption of nutrients. On the other hand, roots pierce and break the clogging in the bottom of the canal, where complex clogging processes are combined, increasing the infiltration rate, despite their direct consumption of water through evapotranspiration and photosynthesis.

Both lines of action were initiated in 2005 (Fernández-Escalante, 2005). Considering the convenience of the green biofilter and the most appropriate plants to be induced to settle in this section, some species have been inventoried which are prone to penetrate the clogging layer, increasing the subsequent passage of water, and decreasing the amount of nutrients in the soil. Most listed species are those hydrophilic herbaceous with an annual cycle, rapid growth, high root expansion and ease of extraction with roots (inventory at MARSOL 2015b).

3) Third triplet element: Artificial wetlands

This three-pond-group is located laterally at the margin of the infiltration canal and reconnected in the northern extreme (figure 5-5). They play a double function, the purification of the water in the vessel (post-treatment) and an environmental function as refuge for wild fauna. As the bottom of the wetland stays slightly higher than that of the parallel canal, water does move all through the ditch.

(a) (b) (c)

Figures 5-5 a) to c): Three-pond-group of artificial wetlands: Sanchón 1 (2,361 m^2) (a & b) and Sanchón 2 (2,915.8 m^2) (c).

The importance of this site as a purification enhancer and a habitat for aquatic species is very relevant. It occupies the functionality of many old temporary ponds that have been desiccated after years of ploughing and pumping, due to an old tradition of decreasing the run-off volume and thus the water table dependent on its infiltration capacity.

Main chemical parameters suffer a quick recovery that sometimes is obviously a consequence of plain dilution, as soon as WWTP spillway gets mixed with the huge volume of river water in the infiltration canal. Nevertheless, seven parameters (see table 5-4) show a different behaviour depending whether they follow the canal or they enter into the artificial wetland (Cu, turbidity, Dissolved Organic Carbon, Fe, P, PO_4 and NH_4). Changes below 12% have been considered irrelevant.

Table 5-4: Parameter comparison with significant differences in canal (3 negative figures) and artificial wetlands (4 positive figures) 17/02/2015.

STATION	Cu mg/l	Turbidity NTU	DOC mg/l	Fe mg/l	P mg/l	PO_4^{3-} mg/l	NH_4^+ mg/l
EV-2 Canal pre WWTP	100%	100%	100%	100%	100%	100%	100%
WWTP water	74%	546%	273%	63%	1902%	1910%	14211%
Artificial Wetland (2A)	84%	94%	125%	92%	130%	130%	263%
EV-4	32%	66%	97%	104%	149%	149%	289%
Difference EV4-AW2a	-53%	-28%	-27%	12%	19%	20%	26%
	Lower in canal			Lower in wetland			

The analysis of 19 biochemical parameters in Santiuste (in MARSOL, 2016) also suits the previous trends:

- Improvement in water quality: Decrease of NO_3 (29%), Cu (68%) and turbidity (34%) in canal (EV-4) related to the inflow from Voltoya River (EV-2).

- Passive biological purification by dilution, sedimentation and biological activity for, at least, Fe, P, phosphates and Ammonia in artificial wetlands (AW2a) in contrast to the canal (EV-4).

EFFECTIVENESS OF REACTIVE FILTERS FOR IN ITINERE TREATMENT

During March-August 2016, a series of tests have been performed treating the reclaimed water with different inorganic and organic reactive filters. The main aim was monitoring its response to interaction with different reactive biofilters in order to improve the quality for MAR. Some disinfection by-products (DBPs) tests were performed as well. Table 5-5 exposes the nature of the filters and the disinfectants tested.

Table 5-5: (Los Arenales, Spain) per campaign.

Nº campaign	Date	Filter
1	15-mar-2016	12-20 Ø siliceous gravel
2	20-apr-2016	20-40 Ø calcareous gravel
3	09-jun-2016	6-12 Ø siliceous grit/gravel+ DBP 50 l Cl_2
4	29-jun-2016	Pine bark + geofabrics
5	14-jul-2016	Pine bark + geofabrics + DBP 50 l H_2O_2
6	27-jul-2016	Pine bark + geofabrics + DBP 100 l Cl_2

17 parameters were analysed in the laboratory: Temperature in situ, O_2 (TDO), Conductivity, BDO_5, COD, TDS, pH, SS, Turbidity (NTU), DOC, nitrogen phases (total, Kjeldahl, nitrates, nitrites and ammonium), Nematodes and *E. coli*.

Figures 5-6: some of the reactive biofilters tested for an *in itinere* treatment.

It is important to remark some facts linked to the test:

- Pine bark was chosen as an easy available sub-product of the local forest production.
- Scarce time of residence (interaction processes have been very short in time), what represents a constraint in the study. There have not been observed important differences in the resulting chemical composition of water using either calcareous or siliceous gravel packs.
- The use of geo-fabrics has also retained a certain amount of suspended solids.
- Chloride doses dropped into the reclaimed water did not retain any amount of residual chloride in the observation points. This fact is attributable to the presence of considerable organic matter content in some stretches inside the pipeline.

The main results for most of the analysed parameters have been:

- BDO_5: The effect on BDO_5 is clearly positive. There is a general descent along the pipeline except for the 2nd, (calcareous gravel as a sifter). DBP test has conducted a progressive decline in this parameter.
- COD: Parallel trend to the previous one.
- TSS: Suspended solids and dissolved solids evolution do not keep a parallelism. The general trend is to decrease, except for the 2nd campaign, using calcareous gravel as a filter, when the tendency was opposite to the general behaviour.
- DOC: This is the unique parameter with a general trend to decrease. The biggest slope was caused by the finest filter. The addition of chloride caused a direct descent.
- Turbidity (NTU): Oddly enough, the trend tends to rise, except for the 3rd test, where the use of a finer filter constituted by grit and gravel caused the expected effect. Even the addition of hydrogen peroxide did not bring down the turbidity; therefore, it has a high inorganic component.
- *E. coli*: The trend has been clearly descending during the spring. Once the summer time began, this sort of bacteria intensified along the circuit. Apparently they were removed *in itinere* by the addition of chloride.

- Total Nitrogen: Trends are not very clear for most of the nitrogen phases, except for nitrates, with a crisp descent trend during the occurrences when both, disinfectants were dropped in the reclaimed water and reactive filter layers were employed.

In summary, all the tested filters have had a certain effect on reclaimed water quality. Maximum was get for the finest ones with a bigger fine particles retention capacity.

The incorporation of a post-treatment reactive layer prior recharge of reclaimed water has had a positive effect on the reduction of groundwater pollutants, enhancing their biological degradation and, consequently, improving the water quality. The treatment with chloride and hydrogen peroxide disinfectants has been successful, reducing the progressive TOC accumulation and its impact on the groundwater.

6. MAR AS A TECHNIQUE FOR RURAL DEVELOPMENT AND TO MINIMIZE AQUIFER OVER-EXPLOITATION RISK

The **over-exploitation of aquifers** has been closely related to rural development in many parts of the world, being a serious risk linked to the irrigation activity when water management is not properly addressed.

Considering MAR as a technique to revoke impacts on water quantity due to the excessive pumping of water resources, there is a logical interconnection between rural development and overexploitation, interpreted as a risk rather than as a usual fact.

According to FAO and UNESCO (2003), *rural development* aims at improving rural people's livelihoods, both socially and environmentally, through better access to assets (natural, physical, human, technological, and social capital), and services, and control over productive capital (in its financial or economic and political forms). All these factors enable rural population to improve their life level on a sustainable and equitable basis.

In practical terms, the different elements have to be combined in order to assess the constraints and to achieve a sustainable growth, enabling rural development in those areas.

This chapter exposes how MAR may intervene allowing a sustainable water resources management and the subsequent agricultural production increase (greater water quantity for irrigation purposes); what entails an associated economic growth (greater irrigation yield and production).

The three different MAR areas at Los Arenales Aquifer share the same purpose: to combat groundwater over-exploitation and to guarantee the irrigation of arable lands. This chapter exposes how MAR faces the over-exploitation of the aquifer and the direct economic consequences.

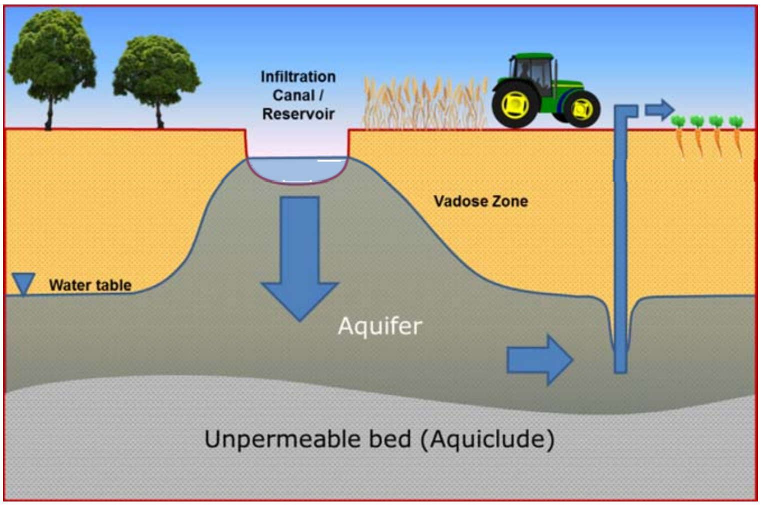


Figure 6-1: MAR and irrigation. Scheme for arable lands.

6.1 Agriculture and Agroindustry at Los Arenales after MAR experiences were applied

Agriculture and industry have traditionally been considered as two unconnected sectors due to their specific features and their role in economic growth. However, they are closely interlinked reinforcing each other. Agroindustry means processing products from agriculture and other primary sectors so the value of those raw materials or intermediate products gets higher as it stays in the area where they were produced.

Despite agroindustry is the main engine of rural development, its implantation degree varies in the three sectors where MAT technique has been applied.

6.1.1 Santiuste basin

The irrigated area of Santiuste de San Juan Bautista is limited to four municipalities: Llano de Olmedo, Villeguillo, Coca and Santiuste de San Juan Bautista. All of them belong to the Irrigation Community (CR Cubeta de Santiuste) who led the proposal to the Water Authority for the construction of MAR facilities and still collaborates in MAR management.

The agriculture is primarily based on cereals; crops like barley (1,406 ha), wheat (680 ha) or rye are predominant. They are usually grown under rain fed systems. Considering the industrial crops group, sunflower has the highest rain fed cultivated area (272 ha while sugar beet has 72 ha exclusively produced under irrigation systems. Other important crops are potato, carrot and leek (grown exclusively with outdoors irrigation system). They are very common in the 3 demo sites. Santiuste also has 113 ha of rain fed vineyard for wine production.

Table 6-1: Distribution of agricultural areas in Santiuste de San Juan Bautista in 2014. JCyL, 2015.

	RAINFED	IRRIGATION	TOTAL
CEREALS	1,783	360	2,143
POTATOES	0	80	80
INDUSTRIAL CROPS	266	90	356
FORAGE CROPS	21	31	52
VEGETABLES	0	17	17

According to official statistics from the four municipalities integrated into this association, the extension of the combined irrigated cropland is around 1,600 ha, although only 750* ha are reported to be beneficiary of the MAR system. These villages show very dislike features, as Coca city is a big rural centre, while Llano de Olmedo is a mostly deserted old village. Nevertheless, the great relevance of agriculture in the rural life is revealed by the number and percentage of agriculture employment and enterprises. Up to 190 employees work in agriculture, with an average of 22%, while 14 agro-industries are registered (13% from the total number of enterprises). Irrigation covers around 10% of cultivated area (table and figure 6-2).

Table 6-2: Main municipal statistics of Santiuste Irrigation Community (INE, 2011)

Municipality	Population (nº)	Agriculture workers (nº)	% Agr Workers	Agriculture enterprises (nº)	% Agr./Ent.	Irrigated Area (ha)	Irrigated / Cultivated Area (%)
Llano de Olmedo	75	4	100%	0	0%	121	8%
Villeguillo	159	9	36%	2	29%	542	34%
Santiuste	631	67	33%	8	31%	568	13%
Coca	2,088	110	17%	4	6%	373	4%
Total (Average*)	2,953	190	22%	14	13%	1,604*	10%

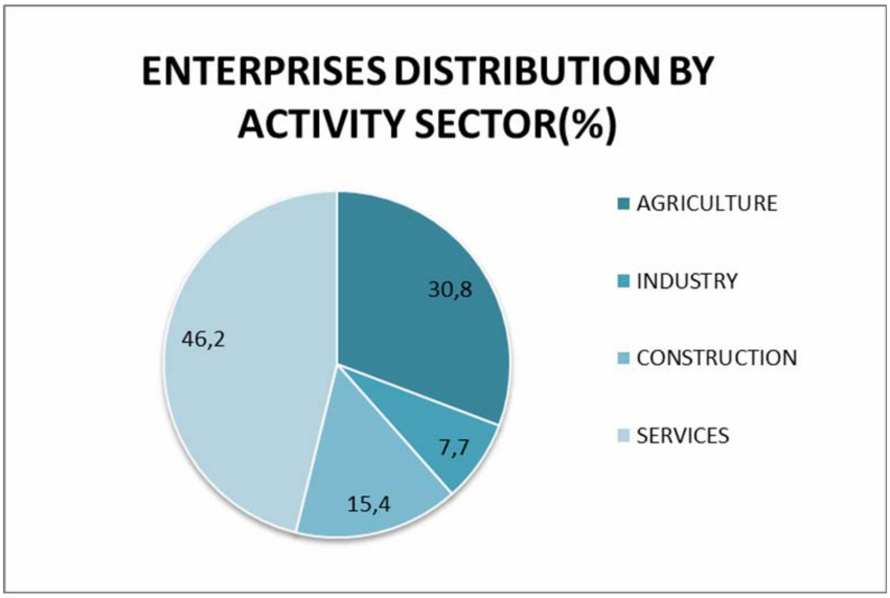


Figure 6-2: Enterprises distribution by activity sector in Santiuste de San Juan Bautista village (INE, 2011).

With respect to irrigated area, the last five-year-evolution (figure 6-3) indicates that irrigated agriculture is getting a growing importance in the zone. Only the little village of Llano de Olmedo registers a flat tendency from 2010 to 2014, according to the Autonomous Government figures captured from the Internet in www.itacyl.es. The evolution of irrigation trend shows a moderately rising slope, except for 2012, when irrigation area fell down (figure 6-3).

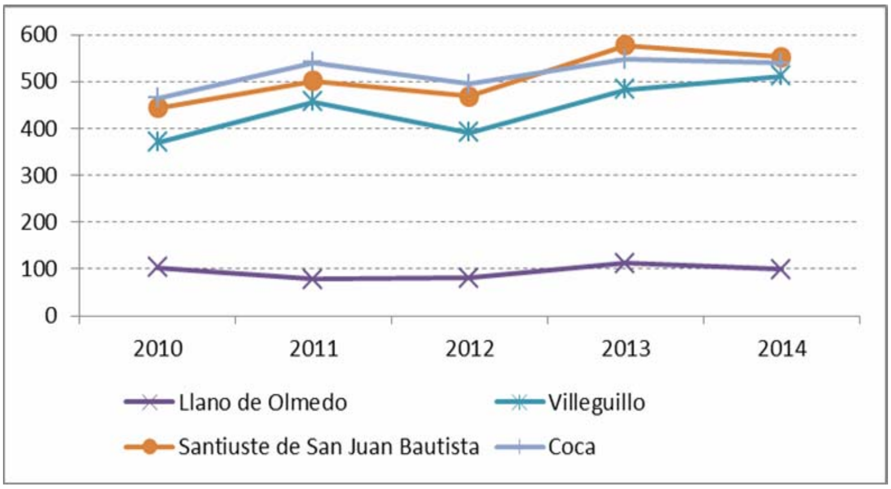


Figure 6-3: Irrigated area evolution (2010-2014) in Santiuste Irrigation Community (JCyL, 2015).

Regarding the crop type, it is primarily based on cereals (chiefly barley, wheat and rye), potato (middle and late season), sunflower and sugar beet. New horticultural crops as carrot, leek (Villeguillo), onion (Coca) and strawberry (both) increase their production.

The differences between crop systems are great; for example, cereals and sunflower are usually rain fed cultivated. On the contrary, sugar beet is exclusively under irrigation systems, as well as carrot and leek (table 6-3 and figure 6-4).

Table 6-3: Main irrigated areas by culture in Santiuste Irrigation Community (Junta de Castilla y León, 2015).

Culture (ha)	2010	2011	2012	2013	2014	Average
Barley	530	551	428	468	412	**477.80**
Wheat	138	176	154	346	316	**242.55**
Potato (late season)	82	116	128	205	257	**178.80**
Potato (middle season)	165	74	58	50	4	**99.13**
Sunflower	83	93	76	44	108	**89.70**
Rye	0	56	88	99	82	**81.25**
Sugar beet	67	64	77	83	105	**79.20**
Carrot	74	62	56	54	62	**63.60**
Leek (Villeguillo)	41	103	55	61	52	**62.40**
Onion	65	77	74	45	44	**61.80**
Strawberry (Coca village)	16	25	38	7	36	**24.40**
TOTAL Main cultures	**1,261**	**1,397**	**1,232**	**1,462**	**1,478**	

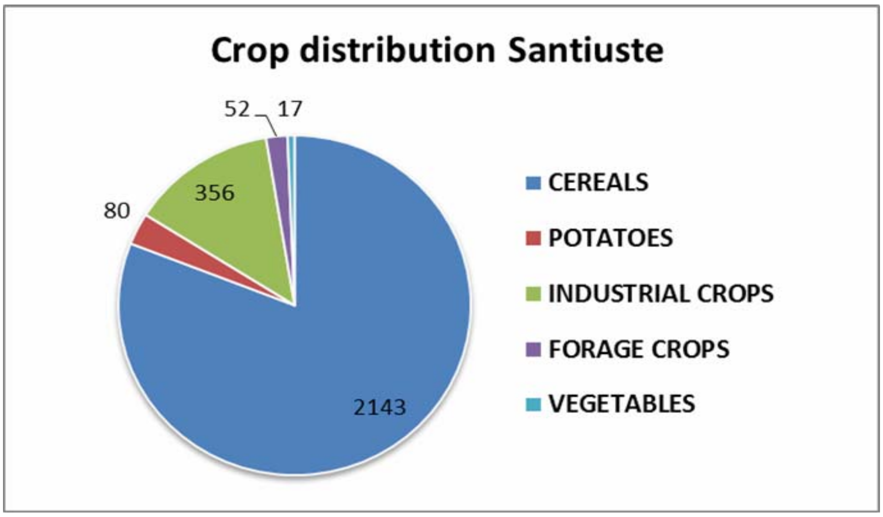


Figure 6-4: Crop distribution in Santiuste de San Juan Bautista village (Junta de Castilla y León, 2015).

There are other municipalities within the influence area of Santiuste basin, such as Coca or Villeguillo, with huge areas of cereals too. But their production of vegetables is greater than in Santiuste, with almost 300 irrigated ha including onion, leek, carrots and spinach.

AGROINDUSTRIES

Agriculture and industry have traditionally been pictured as two separate sectors sharing their economic growth role. However, they can get closely related activities grouped in the term agribusiness or agroindustry, which means industries to process products from agriculture, forestry and fishing sector, whether the processing of raw materials or intermediate products derived from the mentioned sectors.

In this area the main industries relate to agricultural activity including two wineries registered in the "Rueda" Denomination of Origin. In addition there are other industries mostly linked to tubers and vegetables washing, package and storage of vegetables (figure 6-5).

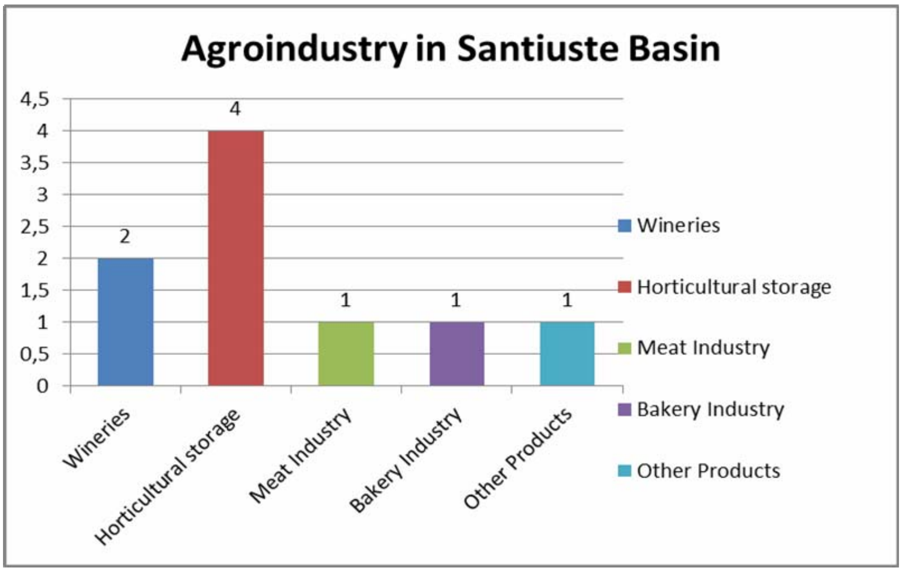


Figure 6-5: Distribution of Agroindustry in Santiuste Basin. Source: RGSEAA, 2016.

The inventory for the agro industrial activity in the area is listed in the Annex II tables (Industrial activity and mobilization in the area linked to MAR experiences). The volumes of water diverted from the Voltoya River for MAR were displayed in the histogram (figure 4-3).

The summary of all the figures exposed is presented in the table 6-11, comparing the importance of MAR in the different sectors of Los Arenales where it is applied.

6.1.2 El Carracillo council

Carracillo district (figure 6-6) stands out in the Spanish agriculture for its production of horticultural products. This region accounts for 80% of vegetable production of Segovia province and 30% of Castilla y León region. This area is the leading producer of leek and strawberry plant of Spain, and third in carrot. It is also worth to note the crop of other vegetables such as onion, potatoes, garlic, sugar beet, sweetcorn and lettuce, among others.

Figure 6-6: Situation of El Carracillo District in Castile and Leon and in Spain.

The total area of the Irrigation Community in El Carracillo reaches 7,500 ha, distributed in 11 municipalities: Arroyo de Cuéllar, Campo de Cuéllar, Chañe, Chatún, Fresneda de Cuéllar, Gomezserracín, Narros de Cuéllar, Remondo, Sanchonuño, Pinarejos and Samboal. 3,000 out of 7,586 ha are irrigated with water related to MAR (table 6-4).

Table 6-4: Municipality list of El Carracillo District. Source: Junta de Castilla y León, 2011.

Municipalities	Irrigation area (has)	Nº of holdings
Arroyo de Cuéllar	718,35	484
Campo de Cuéllar	1,032.31	862
Chañe	1,724.36	1,175
Chatún	557.9	518
Fresneda de Cuéllar	430.06	222
Gomezserracín	1,055.45	1.120
Narros de Cuéllar	754.61	569
Pinarejos	61.05	74
Remondo	450.8	242
Samboal	98.66	119
Sanchonuño	702.66	840
Total	7,586.21	6,225

MAR has been a key factor to boost rural development as well as to combat the aquifer over-exploitation. MAR has increased water availability allowing the transformation of dry lands into irrigated lands and leading to greater productions (as an average, a double). Yields per hectare get duplicated in most cases, and even tripled for the sweet melon case.

The largest part of arable land is covered by cereals, especially wheat and barley, but only a small part is under irrigation systems (about 17%). The production of potatoes is remarkable. As far as industrial crop is concerned; the mostly grown crop is irrigated sugar beet. With regard to vegetable production; farmers dedicate 30% of their agricultural areas to carrot (close to 700 ha), 20% to leek (approximately 500 ha), 5% onion (65 ha) and 4% garlic (48 ha) (table 6-5).

Table 6-5: Distribution of agricultural areas in El Carracillo in 2014. Source: Junta de Castilla y León, 2015.

	RAINFED	IRRIGATION	TOTAL
CEREALS	2,750	588	3,338
POTATOES	228	205	433
INDUSTRIAL CROPS	50	129	179
FORAGE CROPS	52	26	78
VEGETABLES	155	1,019	1,174

According to data taken from Junta de Castile and Leon (Government Agency) there are approximately 200 ha of greenhouses in the region where different vegetables and fruits are grown.

El Carracillo is well known for its production of strawberry mother plants, holding the first position in Spain. About 600 hectares are cultivated, producing about 60 million strawberry plants of four different varieties, supplying greenhouses in Southern Spain, England, Germany, other Southern Mediterranean countries of Europe and Morocco. They also have an important production of fruits, particularly strawberry and raspberry, to supply markets with out-of-season products.

Due to favourable climate conditions, the appropriate properties of the soils and the availability of water, secured by means of MAR technique, this agricultural region presents high yields in the different existing crops, in particular in carrot, ranking in the highest positions in Spain (tables 6-6 and 6-7).

Table 6-6: Yields in El Carracillo. Source: President of El Carracillo Irrigation Community, 2015.

CROP	YIELD (T/HA) OR (Nº PLANTS/HA)
Potatoes	40-50
Carrot	70
Leek	40
Strawberry plant	550,000-600,000
Sugar beet	80

Table 6-7: Crop yields in Castilla y León, 2014. Source: Junta de Castilla y León, 2015.

	Crop Yield (kg/ha)	
	Rain fed	Irrigated
Potato	28,472	48,431
Garlic	5,649	11,058
Sweet melon	7,978	26,478
Wheat	2,977	4,610
Barley	2,446	3,654
Oats	1,906	3,413
Rye	1,789	3,272

Yields per hectare are duplicated in most cases, and even tripled as observed for the sweet melon case.

AGROINDUSTRIES

El Carracillo stands out horticultural industries (figure 6-7). There are around 30 out of the 40 units existing in Segovia province (approximately 75%); due to the significant production of these products, their high quality and the large investment in research and innovation to develop highly demanded crops. These products are prepared and packed by heat treatments, ensuring its conservation while maintaining their texture, flavour, original aroma while retaining all their nutritional properties. They also have a lifespan of up to six months from the packaging date. Although most are specialized in the preparation of carrot and leek, they also transform other products such as onions, sweet corn, red beets, beetroot and endive. Much of this production is exported to France, U.K. and Italy.

The impact of the horticultural industry is so important that the estimated turnover is, roughly, 50 M€ worth.

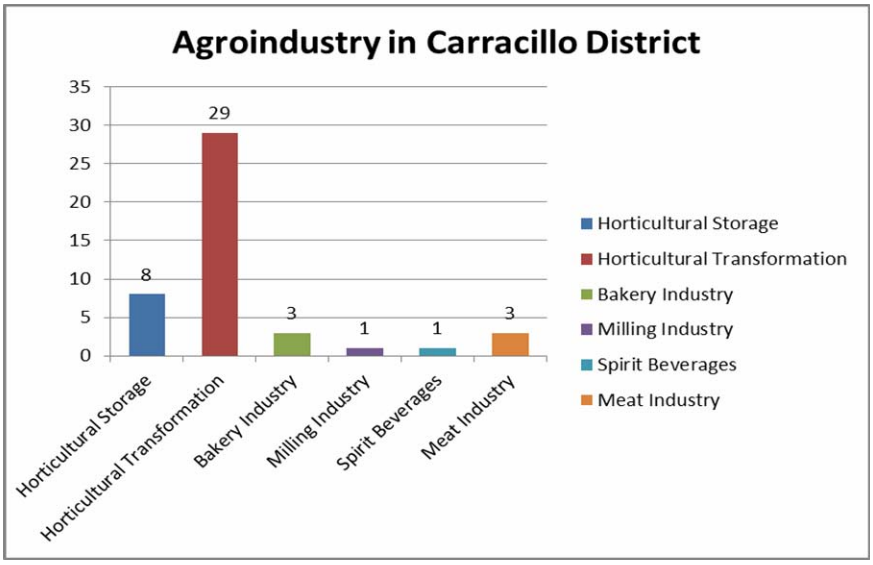


Figure 6-7: Distribution of Agroindustry in El Carracillo District. Source: RGSEAA, 2016 (goo.gl/UIUftL)

BOOSTING RURAL DEVELOPMENT

According to a report published by ITACYL (Agricultural Technology Institute of Castilla y León) the municipalities located in El Carracillo exceeded "broadly" the mean in terms of working age population, from 20 to 64 years old. Thus, if Castilla y León rural area register 7.4 inhabitants recorded between 20 and 64 years old per square kilometre, while in the area of El Carracillo this ratio exceeds 17 inh./km^2. This indicator demonstrates that employment opportunities in this environment are quite superior to the average in the whole Autonomous Community, situation replicated in the density of workers: *"three times higher in El Carracillo than in the rest of the rural area of the region."*

As for occupation; the figure of jobs related to the activities of agriculture and industry is 3.5 times above the average for the region, which has an indirect impact on the services sector. Therefore, in El Carracillo have been recorded 11.29 workers per square kilometre, overwhelming figure compared to 3.73 w/km^2 what is the regional average.

As reported by ITACYL, the number of companies in the area is 1.28 per square kilometre, while in rural areas of Castile and Leon the average ratio is 0.46 i/ km^2 (about a third). The report shows that the effects of horticultural products and their transformation on labour, business, and consequently, the entire socio-economic activity in rural areas is very important, *"multiplying the possibilities in these settings"* concludes the study.

Consequently, irrigated agriculture plays a “vital” role in rural employment, enhancing high employment rates that contribute to the attachment of population in this rural area. Since 2000 the population in the region has decreased by an average of -6%, but this specific area has registered considerable increases; e.g. since MAR began, the municipality of Chañe´s population has increased up to +28% (figure 6-8).

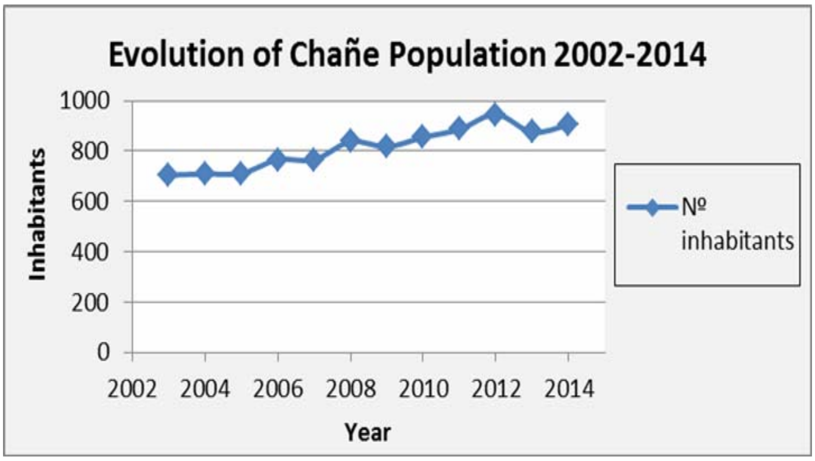


Figure 6-8: Evolution of the population in Chañe village for the period 2002-2014.

The inventory for the agro industrial activity in the area is listed in the annex II.

The figures of the water volume diverted from the river Cega for MAR have been exposed in the histogram of the figure 4-5 as well as in the table 4-7.

6.1.3 Alcazarén area

Though Alcazarén MAR area includes 3 different villages, only Alcazarén (mainly) and Pedrajas use the recharged resource for agriculture. Alcazarén presents very similar social-economic features to previous villages in Los Arenales demo-site (table 6-8).

Table 6-8: Main municipal statistics of Alcazarén (INE, 2012).

INE 2012	Population	Agriculture workers	% Agr Workers	Agriculture enterprises	% Agr./Ent.	Irrigated Area (ha)	Irrigated / cultivated Area (%)
Alcazarén	726	28	21%	6	25%	657	15%

For the last five years the irrigated area has risen in this municipality, except for the winter of 2012. The analysis of the main crops production indicates that some cultivars are clearly increasing its extent (wheat, carrot and leek) even in 2012, while others as sugar beet, potato, barley, rye do not get out of stagnation. MAR has caused a change in the main crop from cereals to new horticultural cultivars under irrigation (figure 6-9).

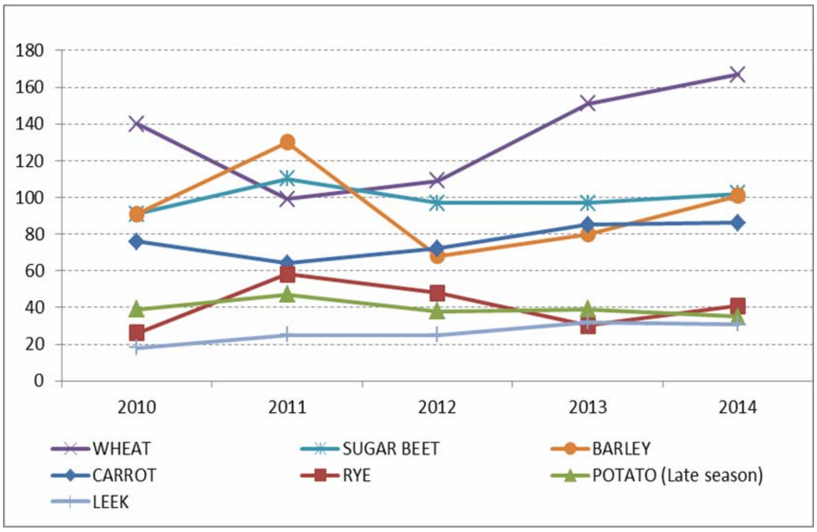


Figure 6-9: Irrigated area evolution (2010-2014) by cultivars in Alcazarén (JCyL, 2015).

Typical crops of the area are cereals (in particular barley), potatoes, sugar beet (97 irrigated ha), sunflower (170 ha with no irrigation), and vegetables, mainly carrot (85 ha) and leek (32 ha). Alcazarén also has 76 ha of rain fed vineyard for wine production (table 6-9).

Table 6-9: Irrigated area in Alcazarén (Junta de Castilla y León, 2015).

	RAINFED	IRRIGATED	TOTAL
CEREALS	717	271	988
POTATOES	0	65	65
INDUSTRIAL CROPS	194	131	325
FORAGE CROPS	34	21	55
VEGETABLES	2	151	153

Regarding Pedrajas de San Esteban, agriculture plays a minor role in the total economy as compared to Alcazarén, although it should be emphasized 102 irrigated hectares dedicated to grow carrot (table 6-10).

Table 6-10: Distribution of agricultural areas in Pedrajas de San Esteban in 2014. Source: Junta de Castilla y León, 2015.

	RAINFED	IRRIGATED	TOTAL
Cereals	459	147	606
Potatoes	0	48	48
Industrial crops	24	18	42
Forage crops	3	3	6
Vegetables	0	133	133

AGROINDUSTRIES

This area is mostly related to vegetable storage and packaging industries, but it is also relevant the pine nut processing industry, due to the extended areas covered by pine forest. Over half of the food-industries present in Pedrajas de San Esteban are related to pine nuts (figure 6-10).

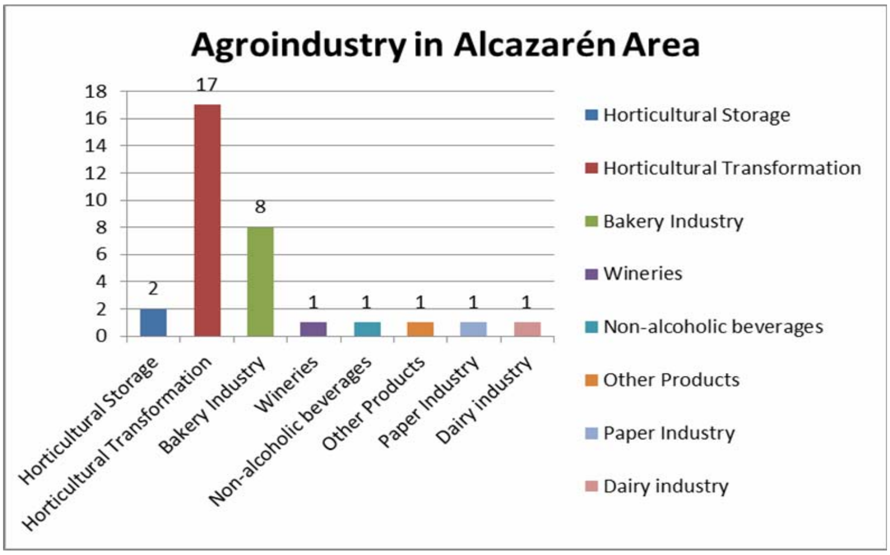


Figure 6-10: Distribution of Agroindustry in Alcazarén Area. Source: RGSEAA, 2016.

The inventory for the agro industrial activity in the area is listed in the annex II.

The figures of the water volume infiltrated into the aquifer either from Pedrajas WWTP, the runoff of the city or diverted from the Pirón River for MAR are exposed in the histogram of the figure 6-11.

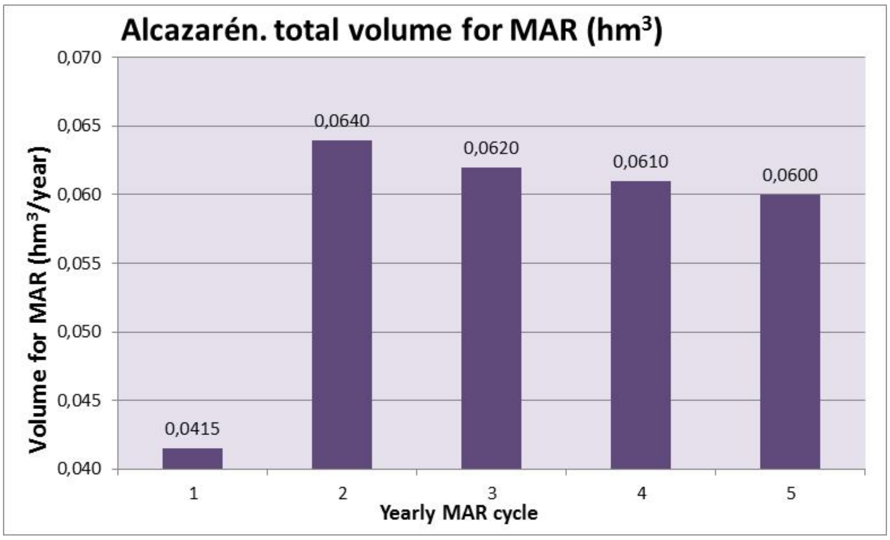


Figure 6-11: Histogram with the volume of water infiltrated in the aquifer by means of MAR technique since the activity began in Alcazarén area (2011-2015).

Table 6-11 exposes the main figures relating irrigation, rural development and MAR to combat over-exploitation in Los Arenales aquifer.

Table 6-11: Summary of economic parameters and cost benefit figures for the main MAR plants at Los Arenales aquifer. Notice that for Alcazarén area, the intervention zone differs from the municipal term´s boundaries.

Parameter	Santiuste	El Carracillo	Alcazarén
MAR facilities construction. Initial cost (€)	3,948,079	5.,273.999	2,200,000
Hectares in irrigation	790	3.500	400-520
Hectares in irrigation before MAR activities began	515	3.000	<400 (n/a)
Arable hectares	3,061	7,586	1,593
Number of commoners in each irrigation community	440	713	190
Total volume employed for MAR since intentional recharge began until 2015 (hm^3)	42.12	31.47	0.287
Years of operability until 2015	14	13	4-5
Ratio recharge/surface (m^3/ha) total	65.59	24.18	0.18
Average annual groundwater extraction (Mm^3/year)	0.21	8	0.06
Contribution for irrigation groundwater proceeding from MAR activity (m^3/ha)	852,6	314,3	1,500
Percentage of water used for irrigation proceeding from MAR activity (%)	27.84	23.8	25.99
Raise of the average groundwater table thanks to MAR (m)	1.47	2.3	0.75
Energy savings thanks to the raise of the groundwater table by MAR [(kW h (%)]	30.4	36	18
Maintenance and operation costs per cubic meter of “MARed” water (€/m^3)	0.05	0.08	n/a

According to these figures, MAR has increased the number of hectares in irrigation, but more importantly has secured a good technique to combat the previous overexploitation of the aquifer.

The number of commoners obtaining a certain profit from the activity changes very slightly since the irrigation community made a new smart distribution of the plot of lands.

The volume of cubic meters per hectare employed for irrigation varies considerably, with a direct dependence of the infiltrated volume.

The contribution for irrigation groundwater proceeding from MAR activity, in m^3/ha, ranges around a 25% as an average, figure that decreases as long as new MAR cycles concur.

Despite the larger water withdrawal from the Aquifer, the groundwater table has risen from the initial level; therefore, we can say MAR is playing an important role reducing the impact of over-exploitation on the groundwater resources.

The cost per cubic meter of water in relation to the initial investment is getting more and more affordable (about 5 c€/m^3) and decreasing every new MAR cycle due to the amortization of the initial investment.

7. SOME EXAMPLES FOR PUBLIC PRIVATE PARTNERSHIP (PPP) SCHEMES AT LOS ARENALES DEMO-SITE

The main interaction between the irrigation communities (private entities) and public institutions has been focused on regulators (river basin authorities) from the “Confederación Hidrográfica del Duero“ (CHD), and electric energy suppliers. Both relations have left remarkable PPP schemes willing to cope with the overexploitation of the aquifer.

7.1 Interrelation between the irrigation communities and the river basin authorities

There have been important changes and lessons learnt along the activity´s development, due to its novelty and also to the previous scarce experience on MAR for agriculture in Spain.

7.1.1 Santiuste basin

The main relation between the irrigation community of Santiuste and the river basin authorities (CHD) has been in respect to the permission to redirect water from the river Voltoya to the MAR ponds and canals. The final authorisation (n/e: C-21.766-SG) limits the maximum volume of derivation to 8.5 hm^3 per year, according to the character of the hydrological year. The maximum instant flow allowed is 1 m^3/s. The condition to this compromise is the maintenance of the flow-rate in Voltoya River (Puente Chico gauge-station in Coca village), where the flow rate must exceed 600 L/s as an ecological commitment.

The maximum volume of water to be used for intentional recharge was maintained at 8.5 hm^3/year between November 1st and April 30th. During the first year of operability the total volume redirected was 2.25 hm^3 with a mean value of 149 L/s in the heading of the structure. These conditions have not been modified since the first campaign.

7.1.1 El Carracillo council

This experience has had a conflict of interest since the beginning, acquiring a certain gravity, bringing up a litigation that had to be solved in the Courts of Justice. The reason was the affection of water detraction to some small hydro-power generation plants several kilometres down the Cega River, due to the larger distraction of water for irrigation. It is important to track and describe this process chronologically, in order to mug up from this experience. The stages have been:

The Decree-Law 9/1999 declares the recharge of the aquifer as an experience for the *“General Interest for the Nation“.* Consequently, the study of environmental impact was *“simplified”,* according to law.

On 1999 December 20th, the Confederación Hidrográfica del Duero (CHD) approved the C. 21.844-SG grant to divert water from Cega river for the next 50 years, with a maximum flow rate of 1,370 l/s and an annual volume limited to 14.2 hm^3, safeguarding a circulating ecological flow of 6,898 l/s downstream. The diversion could only be made between the months of January 1st and April 30th, as long as the ecological requirements were fulfilled.

In 2007 February 22th El Carracillo irrigation community requested a modification of the concession features, to enlarge the water diversion period in two months more (November and December), as well as to reduce the ecological flow-rate from 6,898 L/s to 1,960 L/s. They also proposed the construction of a new gauge station next to the diversion point to be supervised by CHD civil servants.

In 2008 July, the Territorial Service of Environment of Junta de Castilla y León issued the statement of environmental impact, in which it was declared that there were two concessions down the river for electricity generation, demanding, approximately, 4,000 L/s and 1,700 L/s, and the proposed action (a circulating flow-rate of 1,960 litres / second) would not satisfy their requirement.

In 2009 November 24th the Ministry of the Environment authorized, by resolution, to modify the characteristics of the permission, allowing a minimum circulating flow in Cega river of 1.960 L/s between December 1st and April 30th, and a maximum diversion flow rate of 1,370 L/s, giving priority to the demand of the farmers and the economic development of the region.

This resolution was later voided in 2013 by the National High Court of (*Audiencia Naciona)* after the contentious-administrative appeal presented by Cega Energies SL (Fuentepelayo) holder of the previous water rights of 2 hydroelectric plants from Cega River: 2,000 L/s supply for the "Garrido" and 4,000 L/s for "La Ibienza".

In 2015 the irrigation community presented a new proposal requesting an extension of the water rights in a month with a slight reduction of the ecological flow-rate in Cega River. In this occasion the procedure was accompanied by the corresponding environmental impact assessment study subjected to the conventional procedure, with a period for public information and another to receive allegations from third parties. Resolution is still expected nowadays.

Apart from this impact, which can be considered a simple conflict of interests with a smooth approximation of positions, another important element for PPP and DSS is the eventual presence of areas with concentrations of arsenic in groundwater over the limits referred in the Law. The cause is attributed to the weathering of tertiary geological materials with arsenopyrite nuggets. There have also been some complainants who have associated the presence of free arsenic in groundwater to the use of fertilizers, pesticides and additives used in the cattle feed. Some environmental groups have also mentioned the generation of arsenic in combination with iron ox-hydroxides. These allegations, despite having a scarce scientific rigor, have been officially presented to the Basin Authority, in defence of the corresponding interest of one of the parts. In this way certain interested groups have taken advantage of the high social alarm that the concentration of arsenic in groundwater generates.

The final solution will surely be decided by the magistrates of the High Court of Justice, whose sentence should be able to find an agreement between the ecological flow rate, the farmer demands and the possible compensation for the affected hydroelectric suppliers.

7.1.1 Alcazarén area

It is the device with greater diversity regarding the kind of water source (reclaimed water from the WWTP, river water from a dyke and runoff from the roof-tops of Pedrajas village). It has also suffered some setbacks during the implementation phase and the initial operational stage.

- With respect to the **WWTP**, it has become the main source of water of recharge and the unique with a permanents water supply guarantee. It has had technical constraints related to the resultant quality of the reclaimed water prior the *advanced* secondary treatment system was implemented. The process still advances smoothly.

- The **diversion of water from Pirón River**, led by a 900 mm Ø pipe, had a major impediment in the year 2011, when the license was paralyzed due to the fact that a new conflict aroused between neighbour villages: water taken from Segovia province was directed to Valladolid, what brought up some critics in both interested parties. Detractors were able to procrastinate the activity temporarily, to the extent that during 2011 there was only a small volume of fluvial water re-directed (0.01 hm^3), that means a 24% of the total volume used for managed aquifer recharge in that year. Any subsequent water diversion was banned during 2012 and this conflict of interests still expects a final legal resolution.

- The canal conducting **runoff** water from the "unproductive" surface in Pedrajas village had specific quality problems due to the sporadic use of the MAR channel: contaminant processes were accumulated along the MAR conductions and, when precipitation concurred, pollutants were mobilized, without any type of intermediate treatment, until they reach the "connection point" (Q_3 point in the topological scheme of the figure 7-1) where the three sources of water are integrated.

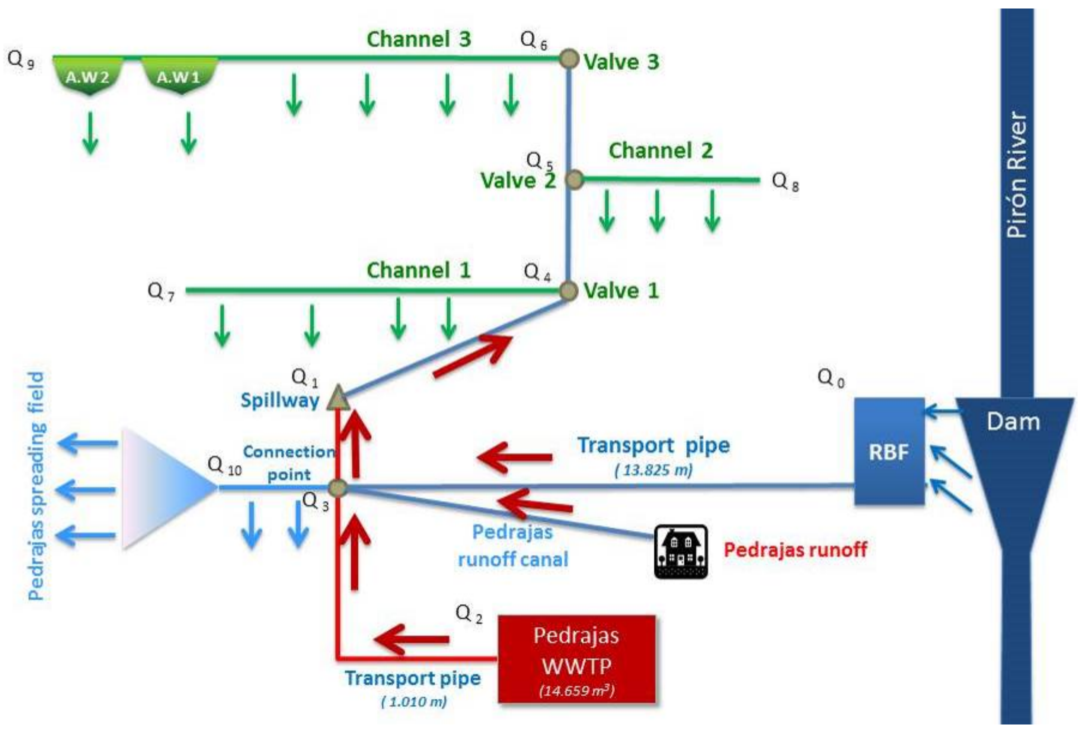


Figure 7-1 Operational sketch for Alcazarén SAT-MAR plant.

7.2 Water and energy efficiency improvements and savings thanks to MAR technique at Los Arenales

7.2.1 Reduction of water consumption for irrigation

The main improvements regarding water savings have been related to the adequacy and modernization of pumping and irrigation systems.

The point of departure was to improve the water crop demands knowledge so as to expand the irrigation network design and management, in order to achieve a proper distribution of the irrigation supply and the progressive automation of the whole system.

The work of the irrigation community has been especially relevant in some tasks, as the performance of the plot rearrangement with similar characteristics (energy demand, water availability) and the reduction of the use of pressure-reducing valves when possible.

Other important line of action applied to reduce the water consumption has been the optimization of the irrigation equipment, supporting activities such as the correct dimensioning of pumps (in number, size and diameter) for the usual flow rates; the progressive adoption of the best pumping technology; installation of variable speed drives on pumps; the establishment of a periodic maintenance protocol for the irrigation facilities; adaptation to new needs detected by the commoners; the improvement of the power factor on electric pumps; the usage of new sensors for the automation of operating and control systems and a permanent leakage monitoring and succeeding reduction of pollution.

7.2.2 Energy consumption savings thanks to MAR

Approximately 40% of the total cost of irrigated farming comes from energy expenditure in Los Arenales.

Pumping energy consumption depends on several factors, such as the energy efficiency of the system; the depth of the water to be extracted (the deeper the most expensive), the required pressure inside the irrigation network; the maximum demand and frequency to satisfy peak volumes, etc.

A single pilot scale test has been done, calculating the energy savings due to the shallower water table as a consequence of MAR activities at El Carracillo District. Taking into account the inventory of wells in the area, with 314 units in exploitation; the mean output water flow volume, ranging 9,957 m^3 per well and year; and the water table variation, with a mean depth before MAR about 6.30 m and 4.00 m after MAR ($\Delta H = +2.30$ m) (figure 7-2).

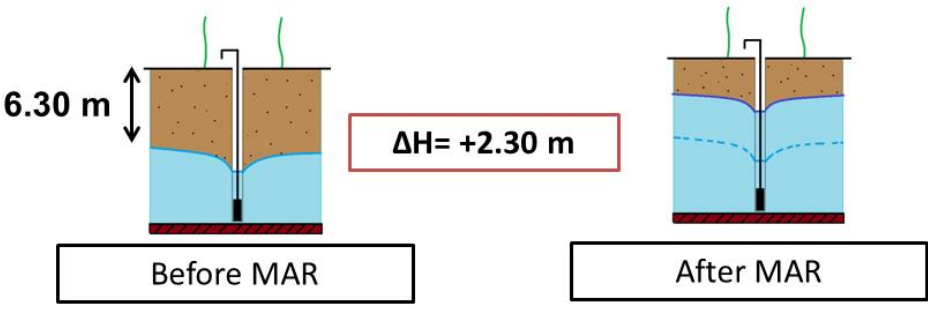


Figure 7-2: Water table increase due to MAR activities at El Carracillo pilot site.

The next question is, what does a 2.30 m water table raise represents in energetic terms? Considering the mean energy consumption for 314 wells, with close to 9,957 m^3/year extractions and a mean water table of +2.30 m increase, the response in kW-h and savings in euros per year are exposed in the figure 7-3.

	Before MAR	After MAR
Energy consumption (kW·h)	76,430	48,430
Energy cost (€/year)	8,180	5,180
	Energy savings of 36%	

Figure 7-3: Energy consumption and its consequent economic savings thanks to MAR activities at El Carracillo demo-site.

In this context, new ideas and lines of actions have been considered by commoners, e.g. changes in the energy source (electric *vs.* diesel pumps); the use of alternative energies, such as solar power, wind power and biomass energy and the permanents technological watching regarding improvements in energy efficiency in comparable scenarios.

The adoption of new alternative systems depends, chiefly, on the Spanish electricity tariff [price per contracted power capacity (kW) and per energy use (kW·h)], feasibility to charge in the electricity network the generated surpluses, the energy-time discrimination, etc. Irrigation communities have begun to conduct cost-efficiency studies to check whether modernization is profitable and what type of measures should be applied firstly in the defence of their economic interests.

According to the experience acquired, the relation with the over-exploitation of aquifers has three remarkable elements:

- MAR technique provides savings in energy consumption and helps to increase the efficiency of the whole irrigation network, simply by saving costs.
- Improvements in water irrigation systems combat over-pumping and enhance environmental conditions, with a positive direct influence on economic outcomes.
- It is recommended performing an energy audit in aquifers where MAR techniques are applied as they can provide a significant improvement in energy efficiency and a factor willing to save expenses, what requires accurate figures to track the trends.

8. LINKING MAR AND DECISION SUPPORT SYSTEMS (DSS) AT LOS ARENALES AQUIFER

DSS and MAR have been permanently interconnected since MAR activity began regarding four main aspects: the selection of *"MAR zones"* (areas where this technique is applicable); the permanent changes in the regulations according to changes in the environmental conditions; changes in water management parameters at multiple scales and, finally, organizational changes.

The evolution of the system itself has caused the permanent design and/or adoption of DSSs, as a mechanism of adaptation to the new changing circumstances and, of course, gaining experience to deploy future DSS on over-exploited aquifers.

8.1 Selection of MAR zones and prioritization

The *MAR zones*, or areas where MAR technique is perfectly feasible, is a task already developed in previous R&D projects. For the whole Spanish territory, for Castilla y León region and for Los Arenales aquifer, there are previous references such as DINA-MAR, 2010 and Tragsatec 2010. These publications have developed a Decision Support System to select the most appropriate areas to perform future MAR activities.

For the whole Spanish territory scale, there is a DSS on the Internet called *"Hydrogeoportal"* that is a GIS viewer to select the MAR zones according to a reductive process (figure 8-1 taken from http://sig3.tragsatec.es/visor_dina-mar/).

This project firstly identified the areas with potential for MAR for the whole Iberian Peninsula and Balearic Islands using characteristics derived from 23 GIS layers of physiographic features, spanning geology, topography, land use, water sources and including existing MAR sites. The work involved evaluations for 24 different types (techniques) of MAR projects, over this whole area accounting for the physiographic features that favour each technique. The scores for each feature for each type of technique were set based on practical considerations and scores were accumulated for each location. A weighting was assigned to each feature by "training" the integrated score for each technique across all the features with the existing MAR sites overlay, so that opportunities for each technique could be more reliably predicted. It was found that there were opportunities for MAR for 16% of the evaluated area and that the additional storage capacity of aquifers in these areas was more than 2.5 times the total storage capacity of all existing surface water dams in Spain (Fernández-Escalante *et al.* 2014).

Overall, this study investigated the technical and economic feasibility of implementing new MAR projects and provides support to decision makers in Spain. The novel mapping provides valuable guidance for the future development of Managed Aquifer Recharge projects for water managers and practitioners.

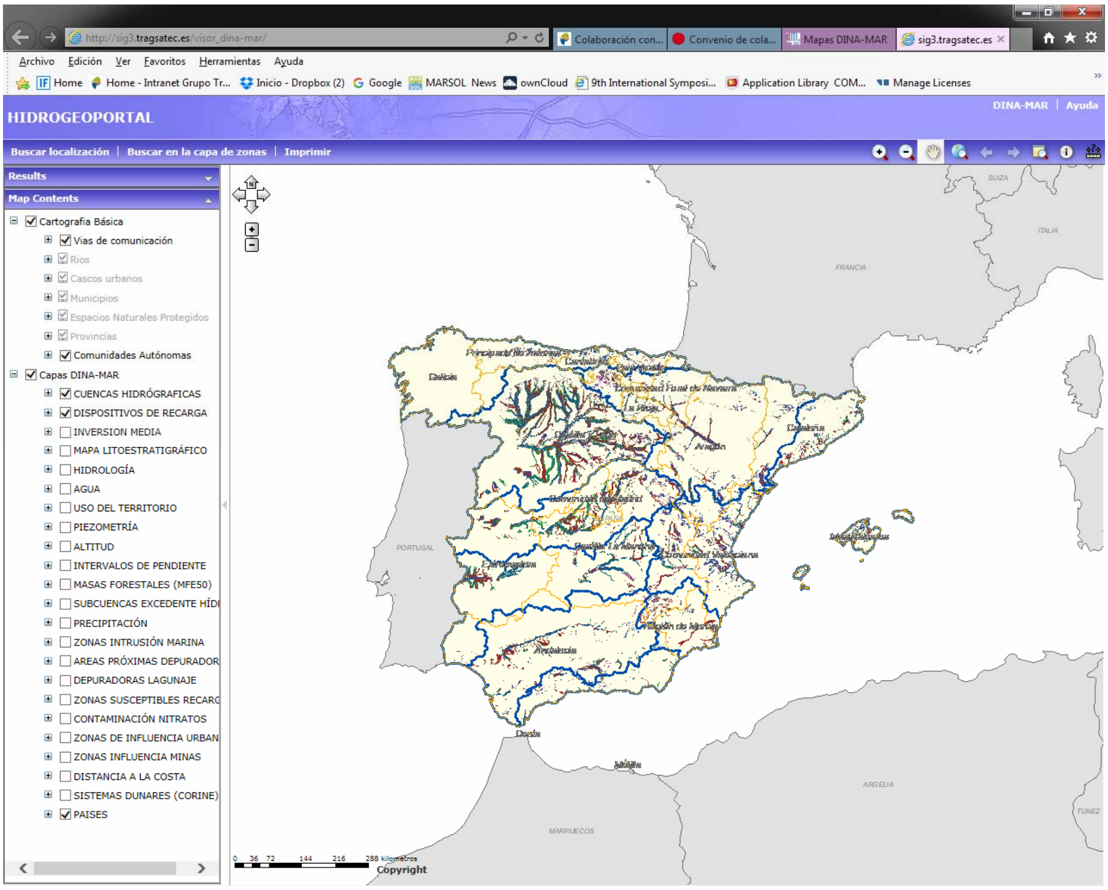


Figure 8-1: Hydrogeoportal DINA-MAR or GIS viewer to find out the MAR zones in the Spanish Iberian Peninsula. Taken from http://sig3.tragsatec.es/visor_dina-mar/

A detailed cartography was also published for DSS at Duero river basin scale, available at: http://www.dina-mar.es/post/2012/03/12/Mapas-DINA-MAR.aspx (figure 8-2).

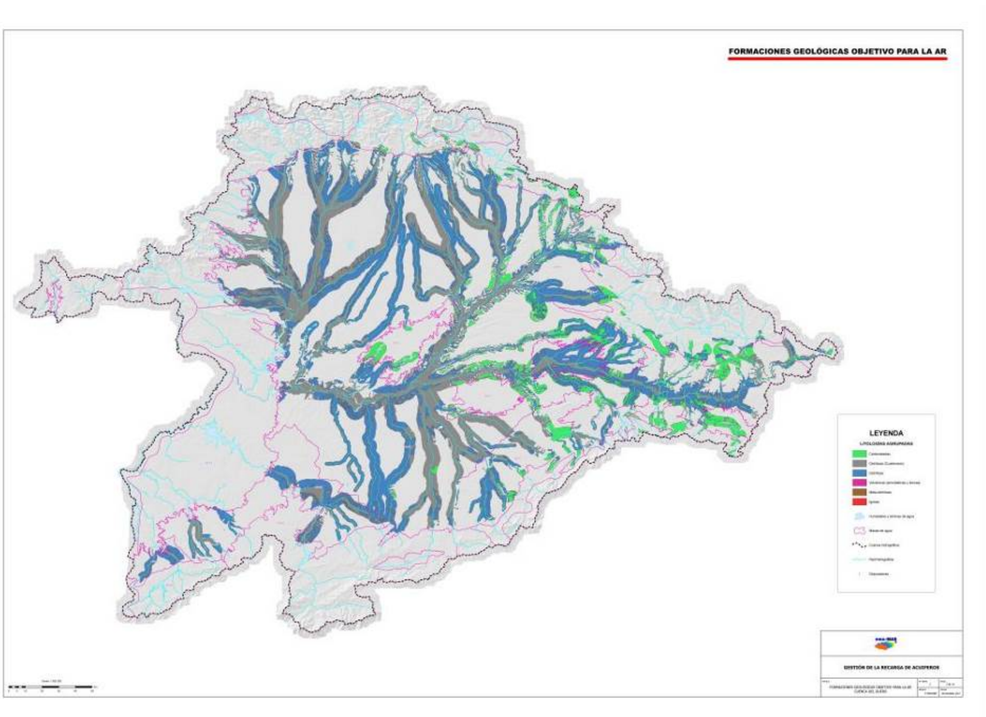


Figure 8-2: MAR zones at Duero river basin scale. Cartography for DSS. Taken from http://www.dina-mar.es/post/2012/03/12/Mapas-DINA-MAR.aspx

A third report for DSS at Duero basin scale paying special attention on Los Arenales aquifer was done by Tragsatec, 2010, in a study for new MAR possibilities and a proposal for 12 expansion areas especially willing for Aquifer artificial recharge or MAR (figure 8-3).

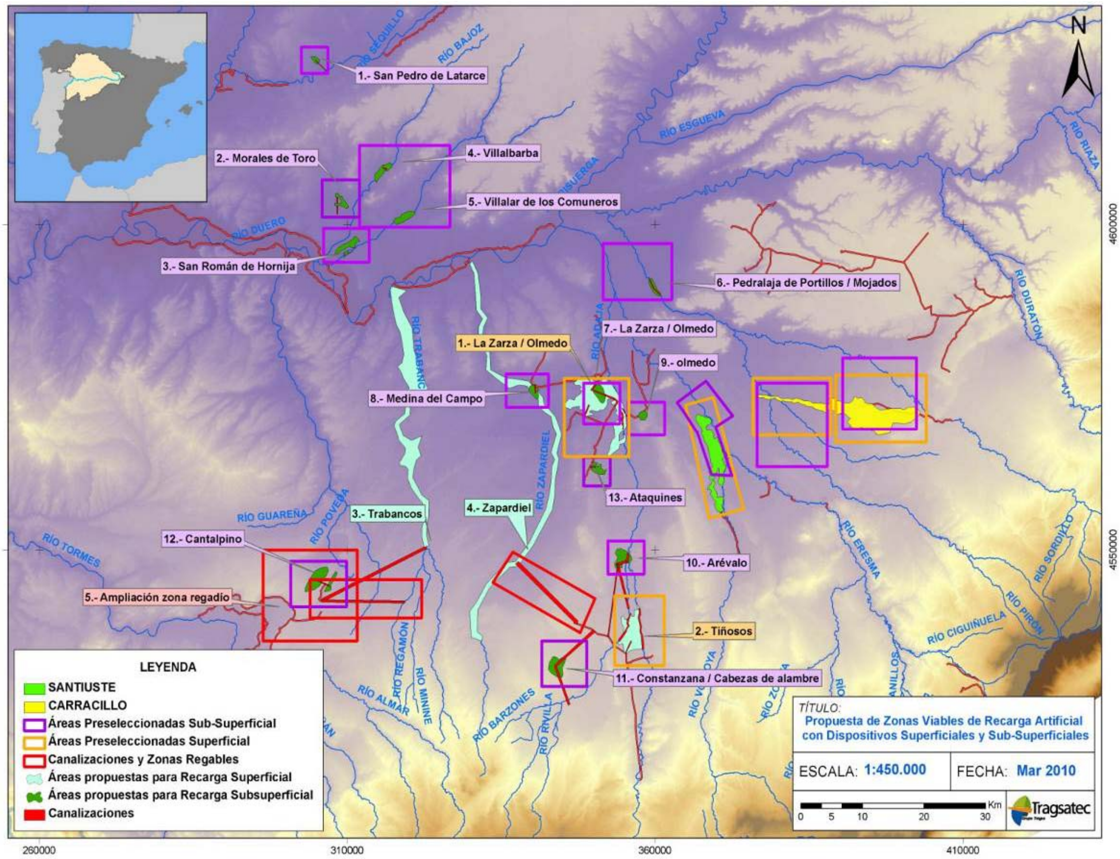


Figure 8-3: MAR zones at Duero river basin scale detail. Taken from Tragsatec, 2010.

8.2 General context and permanent changes in the legal framework

Collective water management in Los Arenales Aquifer relies on irrigation communities, integrated, in general, by a reduced number of commoners who own small plots of land and usually share a common well or borehole to irrigate their lands.

Those aquifers where MAR techniques are applied have developed the biggest irrigation communities in the whole Duero River basin: El Carracillo and La Cubeta de Santiuste. Their largest difference with other associations is that permissions are not only for groundwater extraction but also to divert surface water from Cega and Voltoya rivers, respectively, so as to enhance the storage in the aquifers by means of induced recharge. Allowances from the Duero River Basin Authority were given to both farmer associations for at least 50 years, but they are being used individually according to internal organizational structures (private rights, Section C in the registry) as well as the characteristics are not modified during this episode.

The Duero River Basin Plan editors are aware of the complexity of merging rights for the conjunctive use of surface water and groundwater, despite extractions are taken from the same aquifer or water body. It also forces commoners to make associations for over-exploited aquifers. The vast majority of the farmers are not the owners of the land they work, and, according to the law *(Spanish Water Act)*, the private use of groundwater is reserved exclusively to the owner of the plot to irrigate. This mandate is avoided in the case of associations with an internal structure and a suitable organization and qualified to detour over some of the legal requirements which delimit the use of groundwater.

Within this context, it is also worth to remark the high complexity brought up by the collective use of surface and groundwater, as those permits are processed by different branches of the river basins authorities. In this sense, the legal complexity has been transferred to the hands of civil servants, and commoners must pay attention to fulfil the law, avoiding cumbersome procedures.

The Confederación Hidrográfica del Duero (CHD) tries to avoid new huge associations of commoners, avoiding the fortress they represent by facilitating the constitution of communities from 15 to 20 farmers. That one is apparently a good size to negotiate collective water management rights, due to the ease of handling small groups and their lower capacity as a group of pressure.

In summary, artificial recharge (=MAR) activities entails certain regulation problems in respect to the conjunctive management of surface and groundwater, what requires a new specific framework to regulate the former user's organizational structures. It also requires modifications in the economic-financing regime, in the authorization requirements, in the control mechanisms, etc. in order to overcome the current normative dispersion.

This policy reform should consider the decoupling of the land property and the right to irrigate, to disentangle certain applications by means of integrated water management solutions. It should also study how to enhance the associations as an advantageous scheme for certain reasons, such as the fulfilment of individual obligations (for example all those relating to the counters: installation, maintenance, obligation to register and communicate the results), etc.

This type of actions is willing to increase the water and energy efficiency and the replacement of individual catchments by collective ones, always below the principles of sustainable development involving end-users in water management related issues.

8.3 Water management parameters

8.3.1 Santiuste basin

In the case of Santiuste basin, since MAR activity began in 2002 there have not been insurmountable problems and most of the conflicts have been related to single conflicts of interests among the farmers. The most relevant aroused during the process of concentration celling, and other argues have been related to the *"loss"* of water in perched aquifers towards deeper levels passing through depth boreholes. A third event worthy of mention was the diversion during the 2005/06 hydrological year of 12.5 hm^3 from Voltoya River, volume above the awarded in the concession regime. This incident entailed an important sanction (over 30,000 €) to the community of irrigators and brought up a relatively long administrative procedure with several claims until the final resolution.

It is also frequent the pressure from ecologists and fishermen who advocate for a greater ecological flow-rate in the Voltoya River, in clear defence of their legitimate interests, but without rating the positive socio-economic impact generated by MAR activity and its effect on rural development.

Finally, and although it has been testimonial, it is also worth to highlight the problem of vandalism in rural areas; e.g. in 2011 some sensors and data-loggers were destroyed by thugs, with an important economic replacement costs and the consequent loss of datasets for almost a semester.

There have not been important technical problems except during the first operational stage, when some small floods occurred and damaged some crops. The reaction was to enable two spillways to be used in case intense rain episodes concur with intense MAR actions. In spite of all, affected farmers received compensation.

8.3.1 El Carracillo council

El Carracillo council counts on an extensive culture of irrigation with groundwater and a certain tradition in MAR through ditches. The first MAR devices of certain scale started working by 2002, registering a peak value in the winter of the cycle 2006/07, year in which the first phase of the construction ended and were recharged above 8 hm^3 through channels, infiltration ponds, infiltration fields and great diameter wells.

The first cycles of artificial recharge were also problematic, due to the formal complaint of mini-hydroelectric stations that used the running water in Cega and Pirón rivers to produce electricity. The managers presented allegations still expecting for a final sentence (see paragraph 7-1).

El Carracillo has also registered social complications because of recharging the aquifer, in general in form of conflicts of interests among the commoners, usually resolved internally within the irrigation community.

Regarding the interactions with the Administration, the paragraph 7.1.1 on interrelation between the irrigation communities and the river basin Authority exposes the evolution of the water diversion authorizations. In summary it is worth to outline these characteristics:

- The river basin civil servants supervise the gate to divert water from Cega River for MAR. It is directly managed by the president of the irrigation community.
- There is an operative gauging station close to the diversion point in Cega River monitored in real time by legal enforcement, providing data-sets useful for analyses and studies.
- There is a specific allowance period that is revisable yearly. An environmental minimum flow rate must be respected: 6,898 L/s with a maximum diversion of 1,370 L/s from January to April as well as the total flow rate is minor than 22.4 hm^3/year. Even though these figures are under permanent modification.

The technical problems were scarce due to the huge permeability of the sand in the receiving medium and the improbable risk of flooding.

8.4 Changes in the organizational structure along the period since MAR activity began

It is a basic water management principle that *"water must be assigned under clear criteria and transparency"*. These processes must be accessible for the civil society and for those institutions related to water governance, in order to minimize possible conflicts (López-Gunn & Rica, 2013).

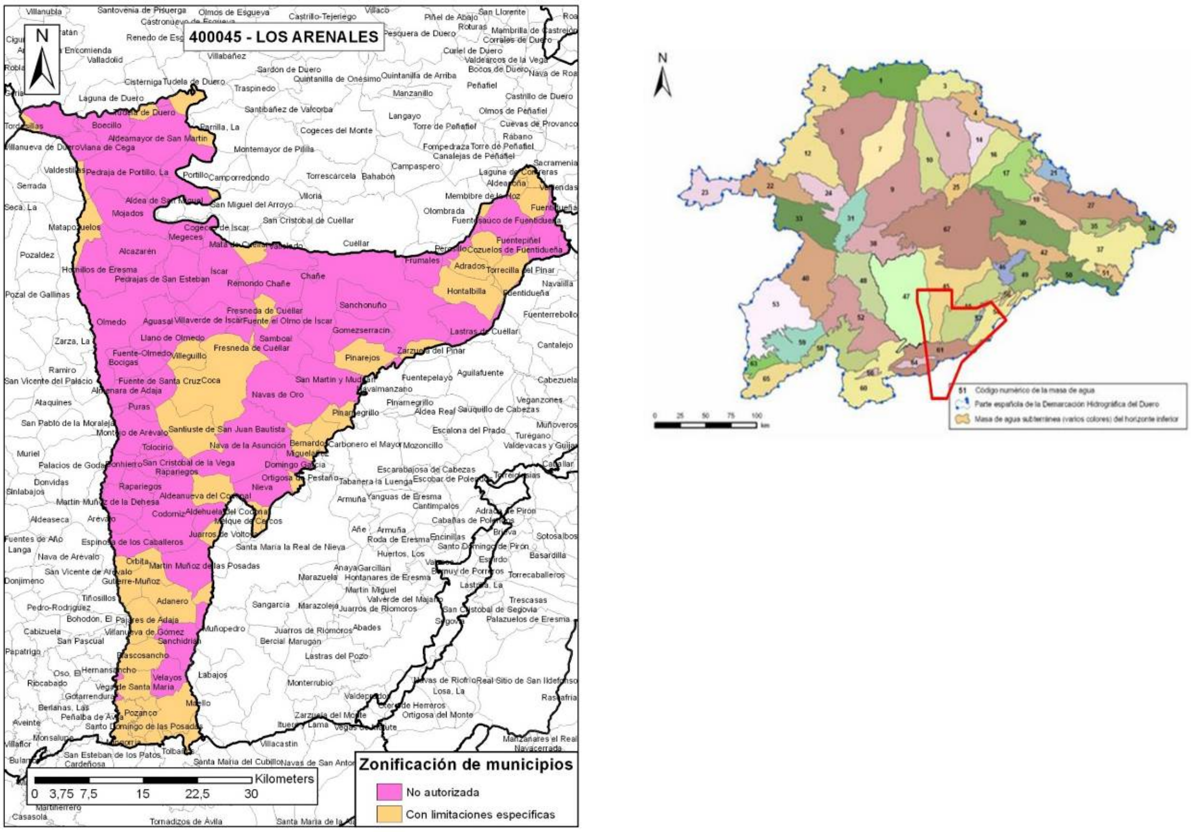
Apart from the transparency, it is advisable to install active participation mechanisms to involve general population in water management issues, either directly or by means of legitimate institutions such as irrigation communities.

The Duero River basin Plan has recently been modified, but it still does not consider MAR as a qualified water management technique, despite the present general claim to enhance and regulate water reuse in Europe. New regulations are included in the Royal Decree R.D.

478/2013 of 21 of June (Normative of the Plan), with scarce consideration on MAR technique although it has become usual in this area; e.g. articles 62 and 66:

- *Art. 62. Groundwater bodies in a bad quality status would be declared in risk after sectors have been split. The own river basin evaluation will be taken into account without external data considerations.*
- *Art. 66 Enhancement of Groundwater users' communities (CUAS): MAR with natural water authorization. 2. Any permission for recharge will require setting up an irrigation community for those receiving benefits from the regulation license.*

Some zonification has already been stablished, such as in relation to new extractions permission (figure 8-4 a), displaying the municipalities with an exploitation index over 75 % and areas with other difficulties for new extractions authorisation (pink colour). The zones with specific drawbacks (in yellow colour) will have to be defined by the river basin authorities or CHD.



Figures 8-4 a) and b): Los Arenales water body's zoning in relation to new extractions permission (unauthorized zone in pink colour and zones with specific limitations in yellow colour) (a), and position inside the Duero River basin (b).

Some of the proposals for the new river basin´s plans, according to Del Barrio, 2014, are:

- To establish a zoning for water bodies in a bad quality status
- To establish a zoning according to the exploitation index distribution
- To establish limitations for water use under permanent revision
- To monitor affected water bodies, either by quantity (over-exploitation) or quality (pollution)
- To monitor and control groundwater extraction.

As a general rule for over-exploited aquifers, water authorities usually avoid stablishing variable tariffs for users, being preferable fixed fees and/or specific restrictions for the different zones. Some authors have analysed other options such as water banking, cap and trade mechanisms, payments awarded in case users reduce their water consumption, the purchase of water extraction rights and/or the closer cooperation among the end-users of the resource (López-Gunn & Rica, 2013). According to these authors, a quotation system for groundwater extractions with compensatory payments can pose long term conflicts, since the overheads will represent a progressively smaller compensation as the phreatic level rises, either naturally or by means of MAR.

On the contrary, water banks management could contribute to reconcile the interests of the farmers with the recovery of aquifer. However, the compliance of the water use restrictions would reduce the agricultural incomes in case no compensation measures were approved. Some of the economic instruments to be discussed and applied can be:

- Purchase of rights of use of groundwater to reduce the demand
- Establishment of an environmental tax to reduce groundwater resources extraction, as a method to internalize a part (or all) of the environmental cost brought by over-exploitation
- A combination of some of the exposed options and instruments.

8.5 Last educational and dissemination activities

During the MARSOL project, two workshops have been organized in the Los Arenales aquifer area (see MARSOL 2015b and 2016) and a third one is planned for the coming months.

Other measures have been the publication of books and articles, the delivery of leaflets and even some posters have been distributed in major city-councils.

The impact of the different dissemination and technology transfer activities has been valued (see MARSOL 2015a) concluding that one effective dissemination technique has been the installation of metal posters in key areas. The three posters developed along the project and set up in the field to disseminate good water management practices in the area have been included as Annex III, as an example of a low cost and high impact activity.

9. CONCLUDING REMARKS

As summary and conclusions, there have been differentiated three different topics: technical and environmental issues, socio-economic (including regulation) aspects, and management (including governance) features.

9.1 TECHNICAL AND ENVIRONMENTAL ISSUES

- It is necessary a *"shift of paradigm"* in the water sector, evolving from water consumption traditional patterns to a circular economy approach in which waste water resource is not considered a waste any longer, but rather an important asset in a context of water scarcity, especially in over-exploited aquifers. In this circumstances techniques such as Managed Aquifer Recharge (MAR) may acquire the importance that deserves.

- There is a direct link between aquifers over-exploitation and rural development. The application of MAR technique has proven a positive impact on the area of Los Arenales aquifer.

- The modernization of the irrigation systems and the adoption of measures to improve the water and energy efficiency are key elements to reduce the over-exploitation impact.

- The water scarcity is faced by integrated water management procedures, combining surface water (from winter surplus) and groundwater (from a unique water body as management cell), fusing that way resources from different origins.

- The water foot-print is getting higher and higher as a great part of the groundwater is being exported abroad in the shape of fruits and vegetables.

- The activities on the receiving medium are becoming a constant with tendency to the application of low cost improvements.

- Pre-treatment keep being the best measure regarding water quality improvement. According to the experiences carried out, the filters had a certain effect on water quality, resulting obviously maximum for the finest ones. The incorporation of a reactive layer prior recharge of reclaimed water (Alcazarén test) has also had a positive effect on the reduction of groundwater pollutants, enhancing their biological degradation and, therefore, improving the quality of the water for MAR.

- Physical, chemical and biochemical processes associated with MAR plants (SAT) represent a natural, passive and affordable way to reduce the presence of certain contaminants, with economic and environmental benefits.

- The environmental requirements are watched by SEPRONA (Environmental Surveillance Department of Rural Police Corps) and river basin civil servants”,.

- Los Arenales aquifer has become an example of multifunctionality regarding recharge systems, as multiple and effective devices and technical solutions have been tested and applied. Most of them can be exported to others systems due to their proven good results, in special for the agro-industry. The different experiences led in Santiuste, El Carracillo and Alcazarén represent an excellent IWRM example.

- The use of reclaimed water for intentional recharge (SAT-MAR) is an excellent opportunity thanks to its integrated character as it combines resources from varied origins and intermittent availability and assures, in general, a qualitative improvement and a safer water supply guarantee.

9.2 SOCIO-ECONOMIC ASPECTS

- The Agro-industry development at Los Arenales aquifer is closely related to MAR since the aquifer was declared provisionally over-exploited in 1995 and MAR was the option chosen to combat this impact.
- Improvements in water irrigation systems enhance the efficiency, the environmental conditions, time availability, supply guarantee and, in short, they imply better economic results.
- MAR has positive effects on job creation and economic growth. Even population is growing up as MAR plays a vital role in reducing rural depopulation rate. MAR has also improved yields and productions, balancing the lower prices of the vegetables in the market during the economic crisis period.
- MAR techniques provide savings in energy consumption (-36%) enhancing the energy efficiency and raising farmer´s incomes. It is recommended an energy audit to provide a significant and accurate improvement in energy efficiency and savings.
- The organizational structures are providing better results in production, control and services than the individual effort, so that association has become a fortress for water management and agro-industry.
- MAR technique increases the availability of water, especially during the summer, increasing the farming activity. It also represents a saving in pumping costs due to the rise of the water table depth in the extraction wells and lower energy consumption.

9.3 REGULATION AND MANAGEMENT ASPECTS, INCLUDING DISSEMINATION

- The modification on the current regulations is a need perfectly justified as little attention is paid to MAR currently, despite it has become a profitable technique.
- Water rights management must reside in Watershed Authorities, avoiding the duplication of powers on water allowance (substantive and environmental organisms).
- The new river basin plans should incorporate "guidelines for artificial recharge", according to the Article 8.2.1.1.2 of the Water Planning Instruction. A prospective basin study of potential MAR sites and techniques would be advisable too.
- MARSOL project has connected the practical technical solutions obtained along the project with dissemination activities for the irrigation community's members. Farmers receive technical support on Sustainable MAR Technical Solutions (SMARTS) regarding their activity in order to make their impact on groundwater resources as low as possible.
- The design and post of metal posters conceived to involve local population in the best use of water in MAR areas has been a direct contribution from MARSOL to rural development at Los Arenales.

- Overall, MAR counts on support and cooperation of the rural society that benefits from a "living system". This fact has been demonstrated by means of the cooperation and participation in the recharge activities of municipalities and irrigation communities, as well as in the constructions, management, maintenance, support to R&D projects, participation in training and dissemination workshops… They also provide an important feedback to those technicians and authorities involved in water management.

- Regarding the last point, Los Arenales demo-site is a successful case of the good relation between technicians and end-users with a direct effect on rural development and a good example to replicate. The doubt is whether this is a singular case of success or it can become a generality.

9.4 GOVERNANCE BARRIERS

- The river basin authorities (substantive organism) allow the permission regarding quantity and quality. Hence, in case the water quality differs from the native water in the aquifer, it is considered a spill (even though the quality is better than the groundwater one for an intended use) and a spill permission must be requested and a fee must be paid. MAR technique should not be considered a pressure on the aquifer or a spill any longer.

- In some cases as those made for the *“General Interest of the Nation”,* the scheme affords specific rights, and beneficiaries are obliged to the maintenance of the devices.

- In general MAR activity is performed by irrigation communities, and the association is the beneficiary. This means that, in theory, all members enjoy water rights and use, but there are often complaints according to the different use of groundwater from persons who “pay a similar fee” but the amount of water spent is different. Also *“MARed”* water even benefits not participant agents in the association who receive any profit from the activity.

- As a matter of fact, the reality is very complex and every case must be studied separately. There are many formulas as well. The common factor might be related to a permanent review of the concessions by the river basin authority, in general annually.

- Finally, the economic analysis and the tested environmental and technical dimension of MAR confirm that it is an effective, convenient and well adapted technique for the water management reality of the XXI century.

10. REFERENCES

- AECOSAN, (2016). Agroindustry Lists. Source: Registro General de Empresas Alimentarias (Agencia Española de Consumo, Seguridad Alimentaria y Nutrición).
- BOE (2007). Real Decreto 1620/2007 de 7 de diciembre que establece el régimen jurídico de la reutilización de las aguas depuradas en España. https://www.boe.es/boe/dias/2007/12/08/pdfs/A50639-50661.pdf.
- Calatrava, J.; Guillem, A. and Martínez-Granados, D. (2011). Análisis de alternativas para la eliminación de la sobreexplotación de acuíferos en el Valle de Guadalentín. Economía Agraria y Recursos Naturales. ISSN: 1578-0732. Vol. 11, 2. (2011). pp. 33-62 (article written in Spanish).
- Custodio, E. (2002). Aquifer overexploitation: what does it mean? Hydrogeology Journal (2002) 10: 254-277. doi:10.1007/s10040-002-0188-6
- Del Barrio, V. (2014). The activity seen from the Duero river basin and the RBMP. MAR4FARM training Workshop, Gomezserracín, Segovia, 2014 October 29-30.
- DINA-MAR (multiauthor) (2010). La gestión de la recarga artificial de acuíferos en el marco del desarrollo sostenible. Desarrollo tecnológico. Coord. Enrique Fdez. Escalante. Serie Hidrogeología Hoy, No 6. Método Gráfico. Available online: http://goo.gl/6lp4m.
- FAO and UNESCO (2003). Education for rural development: towards new policy responses.
- Fernández Escalante, E. (2005). Recarga artificial de acuíferos en cuencas fluviales. Aspectos cualitativos y medioambientales. Criterios técnicos derivados de la experiencia en la Cubeta de Santiuste (Segovia). Tesis Doctoral. Inscripción: septiembre de 2004. Defensa: enero de 2005. Universidad Complutense de Madrid. ISBN: 84-669-2800-6.
- Fernández Escalante, E. (2014). 2002-2012, una década de recarga gestionada. Acuífero de la Cubeta de Santiuste (Castilla y León). Book edited by Tragsa. April 2014. ISBN 84-616-8910-0. 298 pg.
- Fernández Escalante, E.; Calero Gil, R.; San Miguel Fraile, M.A. y Sánchez Serrano, F. (2014). Economic Assessment of Opportunities for Managed Aquifer Recharge Techniques in Spain Using an Advanced Geographic Information System (GIS).. Water 2014, 6(7), 2021-2040; doi:10.3390/w6072021. SCI. Open access. http://www.mdpi.com/journal/water/special_issues/MAR
- Impact of the horticultural sector Study in El Carracillo- Itacyl, 2015. http://www.jcyl.es/web/jcyl/AgriculturaGanaderia/es/Plantilla100Detalle/1246464862173/1248678527953/1284411460866/Comunicacion?utm_source=suscripcion&utm_medium=rss&utm_campaign=rssPagina
- Instituto Nacional de Estadística (INE, 2014). Agricultural Data; Agricultural surface by municipality, crop yields, and prices: Source: Anuario de estadística 2014. Junta de Castilla y León, 2015.
- JCyL, Junta de Castilla y León (2011). Estudio hidrogeológico para la recarga artificial del acuífero pliocuaternario en los términos municipales de Alcazarén, Pedrajas de San Esteban, Íscar, Olmedo y Villaverde De Íscar. Unpublished internal document available to be consulted at JCyL library.
- López-Gunn, E. & Rica, M. (coords.) (2013). Gestión colectiva del agua subterránea en España. Fundación Botín, 2013.
- MARM (2011). Manual para la implantación de sistemas de depuración en pequeñas poblaciones. 460 pg. ISBN 9788449110719.
- MARSOL: Fernández Escalante, E.; Calero Gil, R.; González Herrarte, B.; San Sebastián Sauto, J. and Del Pozo Campos, E. (2015a). "Los Arenales demonstration site characterization. Report on the Los Arenales pilot site improvements". MARSOL deliverable 5-1, 2015-03-31 (restricted access).

- MARSOL: Fernández Escalante, E.; Calero Gil, R.; Villanueva Lago, M. and San Sebastián Sauto, J. (2015b). “Problems and solutions found at “Los Arenales” demonstration site”. MARSOL deliverable 5-2, 2015.11.30 (restricted access).
- MARSOL: Fernández Escalante, E.; Calero Gil, R.; Villanueva Lago, M., San Sebastián Sauto, J; Martínez Tejero, O. and Valiente Blázquez, J.A. (2016). Appropriate MAR methodology and tested know-how for the general rural development. MARSOL deliverable 5-3, 2016-07-31. MARSOL.
- Municipality list of El Carracillo District. Source: Junta de Castilla y León, 2011. http://www.agriculturaganaderia.jcyl.es/web/jcyl/AgriculturaGanaderia/es/Plantilla100DetalleFeed/1246464862173/Noticia/1284172360741/Comunicacion
- Rodríguez-Estrella, T. (2012). The problems of overexploitation of aquifers in semi-arid áreas. HESSD 9, 5729–5756, 2012.
- San Sebastián Sauto, J., Fernández Escalante, E. & González Herrarte, FdeB. (2105): La Recarga Gestionada en Santiuste: 13 Años de Usos y Servicios Múltiples para la Comunidad Rural. - Revista Tierras, 234: pg. 78-85; Valladolid. (article directed at regional farmers written in Spanish).
- San Sebastián, J., Fdez Escalante, E. y González Herrarte F. B. (2015). La demanda gestionada en Santiuste: 13 años de usos y servicios múltiples para la comunidad rural. Tierras Riego magazine 2015, nº 234: 78-85.
- Tragsatec (2010). Propuesta de zonas viables de recarga artificial con dispositivos superficiales y sub-superficiales. Junta de Castilla y León-Tragsatec.
- Winter, T.C., J.W. Harvey, O.L. Franke, and W.M. Alley (1998) Ground Water and Surface Water A Single Resource. US Geological Survey Publications. Circular 1139.

10.1 Web accesses. 2016 November

- http://sig3.tragsatec.es/visor_dina-mar/
- http://www.dina-mar.es/post/2012/03/12/Mapas-DINA-MAR.aspx
- https://es.wikipedia.org/wiki/Sobreexplotaci%C3%B3n_de_acu%C3%ADferos
- INE (2011): www.ine.es
- JCyL, 2015: goo.gl/6WpTP9
- MAR4FARM training workshop: http://www.dina-mar.es/post/2014/11/17/MAR4FARM-PRESENTACIONES-PRESENTATIONS-AVAILABLE-FREELY-ON-THE-INTERNET.aspx
- MARenales movie: http://www.dina-mar.es/videos/MARenales-Film_v7.6.mp4
- MARenales training workshop: http://www.dina-mar.es/post/2015/03/16/PONENCIAS-e2809cMARenalese2809d-CELEBRADO-EL-e2809cTRAINING-WORKSHOPe2809d-DEL-PROYECTO-MARSOL-EN-EL-ACUIFERO-DE-LOS-ARENALES-MARenales-PRESENTATIONS.aspx
- RGSEAA, 2016: goo.gl/UIUftL
- www.marsol.eu
- Youtube: https://youtu.be/Dw22rcEQdiw

11. ANNEXES

11.1 ANNEX I: Solutions to combat groundwater over-exploitation

PROBLEM-SOLUTION (P/S) BINOMIALS

Table 11-1: Problem-solution binomials to combat groundwater over-exploitation regarding climate and extreme water-related events.

PROBLEM-SOLUTION BINOMIALS		ARENALES DEMO SITE		
	Topic	**Problem**	**Solution**	**Explication**
EXTREME WATER-RELATED EVENTS		***- Water scarcity and climate change impact and vulnerability in irrigated agriculture***	**- MAR techniques to increase the storage capacity of the aquifer, and therefore use of surpluses of water resources for irrigation**	**-Most projections of climate change envisage an increase in temperatures and a decrease in precipitation and a resulting reduction in water resources availability as a consequence of both reduced water availability and increased irrigation demands.**
		- Concurrence of heavy rainfall events during artificial recharge activities	**- reduce input flow and speed control, detailed studies of microclimatology and management of floodgates and spillways**	**- The presence of unusually high rainfall events during the period in which aquifer infiltration capacity is lesser, results in flooding of farmland, crop losses, flooding of charging structures receiving huge amounts of sediments mobilized by erosion, clogging different devices and leads to a deterioration of AR devices and, ultimately, of the infiltration capacity.**

Table 11-2: P/S Binomials for water quantity.

PROBLEM-SOLUTION BINOMIALS		LOS ARENALES DEMO SITE		
	Topic	Problem	Solution	Explication
WATER QUANTITY	*Aspects related to the quantity of water (either surface or groundwater)*	*-Groundwater scarcity due to overexploitation of the aquifer*	-Search for alternative water sources derivation	-Seek of surface or underground sources at a reasonable distance and with an appropriate quality.
		-Water storage systems either surface or underground	-Combination of both paying special attention to underground storage	-The storage in the aquifer does not occupy any additional space and has no evaporation issues, only infiltration to deeper strata.
		-Constraints related to the use of the aquifer for the passive distribution of water. It requires a longer time than desired	-Surface/Underground water mixture: canals-aquifer-pipes	-The dissemination of the wells in the area is a key point to achieve the distribution of groundwater all around the site. Some new well had to be dug or drilled in specific points for the associated use of commoners.
		-Groundwater resource extraction by private and uncontrolled pumping	-Organization of groundwater extractions within the irrigation community	-The irrigation community receiving capacity to regulate groundwater distribution among commoners avoiding intrusions from third parties not aggregated into the organization.
		-Scarce collaboration of end-users and decision makers	-Enhance Public-Private Partnership (PPP) and multi-level governance schemes	- The public-private partnership (PPP), innovation and multi-level governance schemes must be more and more approached.

Table 11-3: P/S Binomials for the receiving medium.

PROBLEM-SOLUTION BINOMIALS		LOS ARENALES DEMO SITE		
	Topic	Problem	Solution	Explication
SOIL/AQUIFER	*Aspects related to the receiving medium (soil and aquifer/s)*	*-The best recharge method is unsecured in the long term*	-A combination of different recharge methods is initially designed. The design is resilient and has willingness to be modified if needed	-The combination of infiltration ponds, canal, channels, and wells has to be reviewed eventually so as to adapt the artificial recharge facilities to the changes in the environmental conditions (including socio-economic aspects).
		-The potential of the aquifer to store groundwater was neglected because users were not aware of it	-demonstrations by means of technical solutions: Increase the storage in the heading by direct infiltration and to bring runoff and water from surface catchments	-The potential of the aquifer to store groundwater as a saving-box was unknown and, consequently, neglected. The solutions were awareness campaigns and a demonstration activity based on technological solutions, showing farmers the potential of the technique and convincing them the pros of the activity overcame the cons. *This solution had a social component too.
		-Potential affection of water table oscillations on the edifications and buildings foundations	-Apart from the previous studies for viability, latter studies were conducted studying this possibility	-In Santiuste basin a commoner reported some cracks in his house blaming artificial recharge activity. A specific study was carried out demonstrating the tectonic origin of these stresses. The final decision was made by a Justice Court.
		-Why MAR is only performed in the plot of lands for agriculture but not in the urban nucleus?	-To increase the general MAR culture among the whole population.	-These types of techniques should also be employed in urbanism to increase the natural infiltration rate below cities and villages, to reduce floods and surface run-off. MAR could be implemented in regular decision processes. The use of USDS should be enhanced
		-Rate of infiltration decreases in MAR facilities	-Appropriate cleaning and maintenance	-Criteria applied to clean and maintain MAR facilities are improved in each new cycle. They do not guarantee either an increase of the infiltration capacity or a longer life-span of the structures.

Table 11-4: P/S Binomials for landscape.

PROBLEM-SOLUTION BINOMIALS		LOS ARENALES DEMO SITE		
	Topic	Problem	Solution	Explication
LANDSCAPE	*RECREATION*	*-MAR as a landscape recycling tool*	-Recycling of old closed activities (dumping sites, quarry, mines, abandoned wells)	-The capability of MAR as a way to recycle pre-existing non-operational facilities for recharge is one of its best advantages. Infiltration areas become easily artificial wetlands, giving a new life to these devastated parcels, changing them into new naturalized spots.
	RECYCLING	*-Water reservoirs on surface*	-Subterranean storage and distribution -Plant screens -Naturalization of reservoirs	-MAR itself is a technique that substitute surface reservoirs for aquifer storage but sometimes water ponds are also used for infiltration, clarifying water or temporal storage. Landscape integration measures are applied then.

Table 11-5: P/S Binomials for socio-economy

PROBLEM-SOLUTION BINOMIALS		LOS ARENALES DEMO SITE		
	Topic	Problem	Solution	Explication
SOCIO-ECONOMY	*Binomials regarding socio-economic aspects*	*-Use of MAR water exclusively for irrigation*	-Involvement of other agents broadening the envisaged uses for water supply, industry and environmental purposes	-Though irrigation has always be the main aim of this demo-site, drinking water, industrial and environmental use have got into the stage once the MAR facilities have reasonably recharged the aquifer.
		-Different profit for farmers from MAR activity (aquifer's end-users have the same obligations but the profits from artificial recharge constructions are unbalanced)	-Distribution of the stored water by means of conductions satisfying the demand. In the meantime some compensation mechanism should be established	-Some farmers were receiving a bigger profit from MAR activity than others which plots were far from the MAR facilities. The proposal was to bring water by means of conductions sharing the costs among all commoners. Confidence must be achieved by means of demonstrative projects, cases and examples.
		-Difficult access to technical information for farmers and end-users	-Books, reports, dissemination activities, information regarding the accessibility to the full technical reports	-Some members in the irrigation community have presented some constraints regarding the lack of information and the reasons to justify why some decisions have been made. Apart from dissemination, information regarding where to find the full studies was given to each secretary in the irrigation communities. It is important to count on expert advice to guarantee "future MAR"
		-Interferences between MAR and farmers activities	-Organization and communication between irrigation communities and researchers	-It is important to perform MAR activities without interfering in the farmers' work, so as to facilitate their cooperation.
		- Depopulation.	-Ensure water availability for irrigation.	-To guarantee the irrigation sustainability will allow setting up population in the area.

11.2 ANNEX II: Industrial activity and mobilization in the area linked to MAR experiences

AGROINDUSTRY AT LOS ARENALES AQUIFER

11.2.1 Santiuste basin

	SANTIUSTE	
	NAME	**ENTERPRISE ACTIVITY**
COCA	COMERCIAL PECUARIA SEGOVIANA, S.L.	PRODUCTION OF MEAT PRODUCTS
COCA	JOSE LUIS RODRIGUEZ PALOMARES	BAKERY PRODUCTION AND TRANSFORMATION
COCA	LURESA RESINAS S.L.	PRODUCTION OF ADDITIVES, COLOURINGS AND SWEETENERS
COCA	ABEL ACEVES, S. L.	STORAGE OF DIFFERENT TYPES OF PRODUCTS
COCA	VIVEROS EL PINAR, SOCIEDAD COOPERATIVA	FRESH FRUITS AND VEGETABLES PACKAGING AND IMPORT
COCA	LAGUNA GARCIA, JULIAN	DISTRIBUTION OF AGRICULTURAL AND FOOD PRODUCTS
COCA	JOSE GONZALEZ GARCIA	DISTRIBUTION OF AGRICULTURAL AND FOOD PRODUCTS
COCA	JUAN MANUEL HERNANDEZ CARRION	DISTRIBUTION OF AGRICULTURAL AND FOOD PRODUCTS
	NAME	**ENTERPRISE ACTIVITY**
SANTIUSTE DE SAN JUAN BAUTISTA	AVELINO VEGAS SA	PRODUCTION AND STORAGE OF WINES
SANTIUSTE DE SAN JUAN BAUTISTA	BODEGAS CERROSOL SA	PRODUCTION OF WINES
SANTIUSTE DE SAN JUAN BAUTISTA	S.C. PATATAS BARCELO	PACKAGING OF TUBERS
SANTIUSTE DE SAN JUAN BAUTISTA	ALVARO GARCIA HERRERO	DISTRIBUTION OF AGRICULTURAL AND FOOD PRODUCTS
SANTIUSTE DE SAN JUAN BAUTISTA	JAIME MUÑOZ HERRERO	DISTRIBUTION OF AGRICULTURAL AND FOOD PRODUCTS
SANTIUSTE DE SAN JUAN BAUTISTA	OSCAR ANDRINAL LOPEZ	DISTRIBUTION OF AGRICULTURAL AND FOOD PRODUCTS
SANTIUSTE DE SAN JUAN BAUTISTA	CARLOS ANTONIO MAYER FERNANDEZ	PACKAGING OF TEA AND OTHER VEGETABLES SPECIES
	NAME	**ENTERPRISE ACTIVITY**
VILLEGUILLO	SAT ALCONERA	WHOLESALE OF FRUITS AND VEGETABLES

11.2.2 El Carracillo council

	CARRACILLO	
	NAME	ENTERPRISE ACTIVITY
ARROYO DE CUÉLLAR	PATATAS DAMI, S.L.	STORAGE AND WHOLESALE OF POTATOES
	EL SEÑORITO DE ARROYO, S. L.	STORAGE OF FRESH FRUITS AND VEGETABLES
	ARRANZ NEVADO S.L.	STORAGE OF TUBERS
	CONSTANCIO DE LA FUENTE GOMEZ	DISTRIBUTION OF AGRICULTURAL AND FOOD PRODUCTS

	NAME	ENTERPRISE ACTIVITY
CHAÑE	CULTURA DE LA HUERTA, S.L	WASHING AND SALE OF POTATOES AND VEGETABLE PRODUCTS
	JOSE LUIS LÓPEZ GARCÍA	PRODUCTION AND BAKERY RETAIL
	JUAN MANUEL COCERO ALONSO	WHOLESALE OF VEGETABLES
	Mª PAZ GÓMEZ LAGUNA	PRODUCTION AND BAKERY RETAIL
	SOC.COOP DEL CAMPO GLUS I	STORAGE OF VEGETABLES
	VIVEROS EL PINAR, SOC. COOP.LTDA	CULTIVATION Y WHOLESALE OF FRUITS, VEGETABLES AND STRAWBERRY PLANTS
	ZANAHORIAS EL MANOJILLO, S.L	PREPARATION, PRESERVATION AND WHOLESALE OF VEGETABLES
	HORPIN S.C.	STORAGE OF FRESH FRUITS AND VEGETABLES
	HORTICOLAS BERMEJO MANSO, S. L. N. E.	STORAGE OF FRESH FRUITS AND VEGETABLES

	NAME	ENTERPRISE ACTIVITY
CHATÚN	HORTAFERCAR SOCIEDAD COOPERATIVA	STORAGE OF FRESH FRUITS, MUSHROOMS AND VEGETABLES

	NAME	ENTERPRISE ACTIVITY
FRESNEDA DE	MICRONIZADOS ACEMAR SL	PRODUCTION OF GRAIN MILL PRODUCTS

	CARRACILLO	
	NAME	**ENTERPRISE ACTIVITY**
CUÉLLAR	PIÑONES GONZALEZ, S. L.	DISTRIBUTION, PACKAGING, TRANSFORMATION AND STORAGE OF DRIED AND DEHYDRATED VEGETABLE PRODUCTS

	NAME	**ENTERPRISE ACTIVITY**
GOMEZSERRACÍN	EL PINAR DEL CARRACILLO, SOC. COOP. LTDA	WASHING, PACKAGING AND WHOLESALE OF HORTICULTURAL PRODUCTS
	FUENTE PINILLA, S.L.	WASHING, PACKAGING AND WHOLESALE OF HORTICULTURAL PRODUCTS
	MARTÍN CUESTA, S.A.	PRODUCTION AND WHOLESALE OF MEAT PRODUCTS
	LUIS FELIPE GARCÍA GARCÍA	PRODUCTION AND BAKERY RETAIL
	PUERROS ESPERANZA, S.L.	STORAGE OF FRESH FRUITS, MUSHROOMS AND VEGETABLES
	C. B. HIJOS DE CLEMENTE GONZALEZ	STORAGE OF FRESH FRUITS, MUSHROOMS AND VEGETABLES
	S. C. HORTALIZAS LOS CLAVELES	PACKAGING OF FRESH FRUITS, MUSHROOMS AND VEGETABLES
	JOSE ANTONIO MUÑOZ GONZALEZ	PACKAGING OF FRESH FRUITS, MUSHROOMS AND VEGETABLES
	HORTIGOVIA S.C.	PACKAGING OF FRESH FRUITS, MUSHROOMS AND VEGETABLES
	AGRICOLA VILLENA, COOPERATIVA VALENCIANA	PACKAGING OF FRESH FRUITS, MUSHROOMS AND VEGETABLES
	LOZANO SAN DEOGRACIAS, ANTONIO	DISTRIBUTION OF AGRICULTURAL AND FOOD PRODUCTS

	NAME	**ENTERPRISE ACTIVITY**
NARROS	ZANAHORIAS EL MANOJILLO, SOCIEDAD COOPERATIVA	PACKAGING OF FRESH FRUITS, MUSHROOMS AND VEGETABLES

	NAME	**ENTERPRISE ACTIVITY**
SANCHONUÑO	ARRANZ NEVADO, S.L.	WHOLESALE OF SEEDS, PHYTOSANITARY PRODUCTS AND POTATOES FOR CONSUMPTION AND CULTIVATION
	HIJOS DE TEODORO MUÑOZ, S.L.	PACKAGING, STORING AND WHOLESALE OF FRUITS AND VEGETABLES
	SOC. COOP. DEL CAMPO DE GLUS I	PACKAGING AND WHOLESALE OF CEREALS AND VEGETABLES

	CARRACILLO	
	NAME	**ENTERPRISE ACTIVITY**
	LAS LAGUNAS DE SANCHONUÑO, S.A	PREPARATION AND WHOLESALE OF VEGETABLES
	LA FLOR DEL CARRACILLO, S.L.	WHOLESALE OF VEGETABLES
	ULTRACONGELADOS DEL DUERO SL	PROCESSING AND PRESERVING OF FRUITS AND VEGETABLES
	SANCHONAR SL	PROCESSING AND PRESERVING OF POULTRY PRODUCTS
	HUERTA CASTELLANA, S.A.	PACKAGING OF FRESH FRUITS, MUSHROOMS AND VEGETABLES AND PRODUCTION OF FROZEN AND DEEP-FROZEN VEGETABLE PRODUCTS
	HORTALIZAS LAS ADOBERAS, S.L.	PRODUCTION OF VEGETABLES PRESERVES AND FRESH VEGETABLES IMPORT
	MIGUEL MELCHOR GOMEZ	DISTRIBUTION OF AGRICULTURAL AND FOOD PRODUCTS
	SABOR DE SEGOVIA, S.L.	PRODUCTION OF MEAT PRODUCTS

	NAME	ENTERPRISE ACTIVITY
REMONDO	JOSE ANTONIO GARCÍA GARCÍA	PACKAGING AND WHOLESALE OF VEGETABLES
	COMERCIAL AGRICOLA DEL BARQUILLO COABAR SOCIEDAD LIMITADA	PROCESSING AND PRESERVING OF FRUITS AND VEGETABLES
	REMONDO DE LA CALLE S.L.	PACKAGING OF FRESH FRUITS, MUSHROOMS, TUBERS AND VEGETABLES
	VEGAPIRON, S. L.	STORAGE OF TUBERS
	ENRIQUE Y FELIX DE DIEGO, S. L.	STORAGE OF TUBERS

	NAME	ENTERPRISE ACTIVITY
SAMBOAL	CALLE DE PABLOS SOCIEDAD LIMITADA	PRODUCTION OF SPIRIT AND SPIRIT-BASED BEVERAGES
	JORGE ALVAREZ ARRIBAS	DISTRIBUTION OF AGRICULTURAL AND FOOD PRODUCTS
	IDEALFRUITS, S.L.	IMPORT AND PACKAGING OF FRESH VEGETABLES

11.2.3 Alcazarén area

	ALCAZARÉN	
	NAME	ENTERPRISE ACTIVITY
ALCAZARÉN	HORTICOLAS MURILLO SL	PACKAGING AND IMPORT OF FRESH FRUITS, MUSHROOMS, TUBERS AND VEGETABLES
	VINOLOGICA SL	PRODUCTION OF WINES
	FRUTOS SECOS ALCAZAREN, S. L.	PACKAGING, DISTRIBUTION AND STORAGE OF DIFFERENT DRIED FRUITS
	GRANJA PINILLA, S. L.	EGG PACKING CENTER

	NAME	ENTERPRISE ACTIVITY
PEDRAJAS DE SAN ESTEBAN	BOLLERIA LLORENTE MARTIN SL	PRODUCTION OF BISCUITS, PASTRY AND OTHER BAKERY PRODUCTS
	CONSERVAS FILITO SL	PRODUCTION OF PRESERVED VEGETABLES
	LUIS Y JOAQUIN LOZANO SL	PACKAGING, PRODUCTION AND IMPORT OF DRIED AND DEHYDRATED VEGETABLE PRODUCTS
	SOLUCIONES DE PANADERIA SL	BREAD, BAKERY AND PASTRIES PRODUCTION
	RAUL ARRANZ PEREZ	PASTRIES, CONFECTIONERY AND BAKERY PRODUCTION
	ANDRES VELASCO ARIAS	PASTRIES, CONFECTIONERY AND BAKERY PRODUCTION
	JOSE LUIS VELA ESTEBAN	PASTRIES, CONFECTIONERY AND BAKERY PRODUCTION
	PIÑONES IMPORT - EXPORT 97, S. L.	PRODUCTION OF DRIED AND DEHYDRATED VEGETABLE PRODUCTS
	PIÑONES DE CASTILLA S.A.	PRODUCTION AND IMPORT OF DRIED AND DEHYDRATED VEGETABLE PRODUCTS
	PIÑONES GARCIA MARTIN, S. L.	PRODUCTION, STORAGE AND DISTRIBUTION OF DRIED AND DEHYDRATED VEGETABLE PRODUCTS
	C. B. HIJOS DE APOLINAR	PRODUCTION, PACKAGING AND IMPORT OF DRIED AND DEHYDRATED VEGETABLE PRODUCTS

	ALCAZARÉN	
	NAME	ENTERPRISE ACTIVITY
	FRUTOS SECOS FELIX HERRERO MUÑOZ, S. L.	PRODUCTION, STORAGE, IMPORT AND DISTRIBUTION OF DRIED AND DEHYDRATED VEGETABLE PRODUCTS
	HERNANSANZ GUTIERREZ, JULIAN	PRODUCTION AND PACKAGING OF SOFT DRINKS
	PRODUCTOS TIERRA DE PINARES C.B.	BREAD, BAKERY AND PASTRIES PRODUCTION
	DAVID MARTIN SANZ	PASTRIES, CONFECTIONERY AND BAKERY PRODUCTION
	MARIANO MATE ARRATIA	PRODUCTION OF DRIED AND DEHYDRATED VEGETABLE PRODUCTS
	SANZ ENVASES DE PAPEL, S. L.	TRANSFORMATION OF PAPER AND PAPERBOARD
	PIÑONES MUÑOZ LOZANO, S. L.	PRODUCTION OF DRIED AND DEHYDRATED VEGETABLE PRODUCTS
	HIJOS DE EULALIO ESCARDA, S. L.	CHEESE, CURD, COTTAGE AND FERMENTED MILK PRODUCTS
	PIÑONES HERRERO HERRERO, S. L.	PRODUCTION OF DRIED AND DEHYDRATED VEGETABLE PRODUCTS
	BIOPIÑON, S. L.	PRODUCTION AND IMPORT OF DRIED AND DEHYDRATED VEGETABLE PRODUCTS
	PIÑONES HIJOS DE LUIS SANZ, S. L.	PRODUCTION OF DRIED AND DEHYDRATED VEGETABLE PRODUCTS
	SOCIEDAD COOPERATIVA PIÑON-SOL C Y L	PRODUCTION OF DRIED AND DEHYDRATED VEGETABLE PRODUCTS
	JOSE MARIA SANZ ROMO	PRODUCTION, PACKAGING AND IMPORT OF DRIED AND DEHYDRATED VEGETABLE PRODUCTS
	PIÑONES GONZALEZ SANZ, S. L.	PRODUCTION OF DRIED AND DEHYDRATED VEGETABLE PRODUCTS
	MARIA GARCIA LOPEZ	BREAD, BAKERY AND PASTRIES PRODUCTION
	PAMARAL PATATAS, S.L.	PACKAGING OF TUBERS
	SANDRA DE BLAS SANZ	PRODUCTION OF DRIED AND DEHYDRATED VEGETABLE PRODUCTS

11.3 ANNEX III: Some exemplary educational and dissemination activities

METAL POSTERS FOR WATER MANAGEMENT DISSEMINATION DIRECTED AT FARMERS AND RURAL POPULATION INSTALLED AT LOS ARENALES AQUIFER AREA

11.3.1 Santiuste basin

11.3.2 El Carracillo council

11.3.3 Alcazarén area