

## GROUNDWATER IN THE PLAIN OF THE CRAU (SOUTH-EAST OF FRANCE): BETWEEN HISTORICAL ABUNDANCE AND MODERN VULNERABILITY

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### Abstract

The plain of the Crau (520 km<sup>2</sup>), paleo-delta of the Durance delta in the Western part of the region of Marseille, is characterized by the absence of natural surface of hydrological system. But this plain has abundant groundwater that is 2/3 exogenously recharged, between April and September (hot and dry season), by regular flooding of 12 000 ha of hay meadows, which cover a part of its territory. Changes in land use patterns, characterized by a decrease of the surface submerged for urbanization profile and other economic activity as well as water pollution by modern economic activities (pesticides, many transportation links, industrial emissions ...) and therefore the question of the future of 80 million m<sup>3</sup> of water form essential issues each year for the population, agriculture and industry. The protection and maintenance of this groundwater, which has a crucial economic importance for the region, is a major territorial issue.

**Keywords:** groundwater, Crau plain, flood irrigation, territorial management

### INTRODUCTION

About fifty kilometers west of Marseille, the Crau covers 520 km<sup>2</sup>, in a triangle that goes from the southern border of the Alpilles hills (Salon-de-Provence) to the Mediterranean Sea (Gulf of Fos-sur-Mer) and Rh ne River (Arles) (Fig. 1). This plain is a paleo-delta formed by Quaternary alluvium deposited in an ancient delta of the Durance, when it was a river rushing straight into the Mediterranean. In the Crau, there is no natural surface water system, but groundwater is abundant and recharged mainly by irrigation of a part of the Crau for agriculture purposes. This irrigation, which began in the late sixteenth century, as well as other human actions on the environment, explains the Crau's original landscape and the recent decades of environmental damage affecting the water. Although this groundwater remains abundant, a strong growth in demand challenges local actors and recently several pumping had to be abandoned due to lack of water.



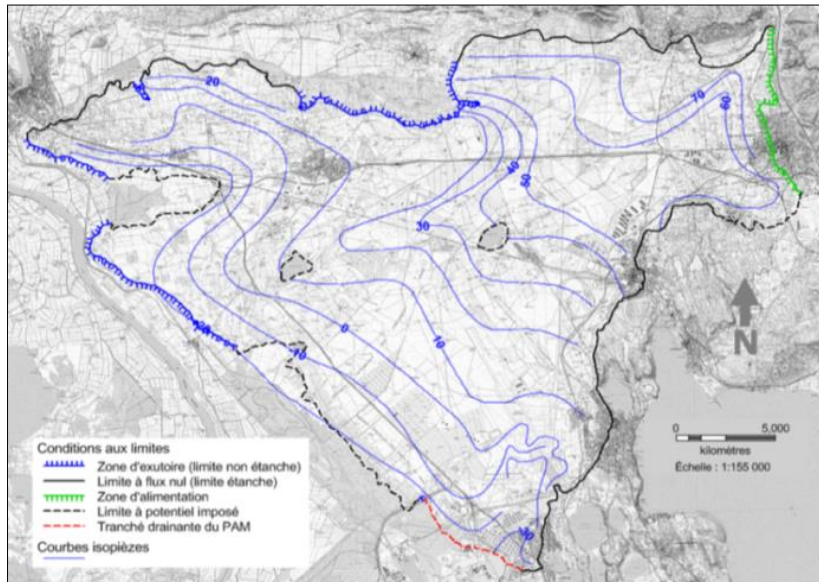
**Figure 1.** Approximate boundaries of the Crau biome, principal roadways and boundaries of urban areas (source: E. Gaba, in Wikipedia)

The question is now to understand this rather unique system in order to protect it, as it secures the supply of good quality water for the region.

## I. The landscaped contrast of the *Cravenc Pays*

The Crau plain is a wide layer of rollers, sloping from the east of Alpilles Massif to the Rhone River and the Mediterranean Sea (Fig. 2). Phases of transgressions and regressions during the Pliocene led to the establishment of a deposit of clay and sandy marl (Miocene-Pliocene) to the north, and argillaceous sandstone or molasses (Miocene) to the south that form the bedrock of the Crau. These “rollers outcrop » locally called the "*Coussoul*") are the classic "natural" image of this plain, which offers different

landscapes depending on the presence or absence of water surface. The curves that connect the points of equal elevation of groundwater levels indicate that groundwater flows follow a northeast-southwest branch (Fig. 2), and that the limit emergence consists of marshes. The depth of the upper limit of groundwater relative to the ground level lies between 25 m. in upstream and 0.3 m in downstream sectors (Seraphin, 2013). This fossil delta, consisting of permeable gravel, explains the formation of the aquifer of the Crau plain and the lack of any natural drainage network.



**Figure 2.** Hydrogeological context of the Crau (BRGM, 1996).

Values are in meters

For the last three centuries, hydraulic works have gradually allowed the progressive irrigation by summer flood in a part of the Crau and this has dramatically changed the landscape, which used to be characterized by great diversity. In the north, the landscape of irrigated hedgerow plots and cultivated fields, as well as orchards or gardening green is the south, the landscape was already uniformly steppe to the sea in the early twentieth century, in recent decades is partially equipped for the irrigation to the row or drip, mainly for fruit, the rest of the area is still uncultivated over large areas dry most of the time. The plain of the Crau is also a strong extension of space and habitat areas of industrial, military and commercial area. Due to the passage of pine line from the Fos Industrial Port Area to the North of France and the Western Europe, recent and rapid changes are causing disruptions to the groundwater, but also overall to a unique ecosystem in the steppe part or the green part both near the *Parc Naturel Régional de Camargue*.

Two main types of landscapes are described here. Two other types of areas exist in the Crau (The Wet Crau and the areas strongly influenced by human activities), which have less interest for this study.

### 1.1. The dry Crau (the *Coussoul*)

The *Coussoul* is an open stony steppe landscape, mainly used for sheep grazing between October and March. This space hosts exceptional flora and fauna and a unique ecosystem specifically related to an ancestral pastoralism. Few sheep and some wells stand of the horizon of this monotonous flatland, a few meters above sea level. Summer transhumance is a traditional practice in the Crau, like another plains and dry hills of Provence. It allows the feeding of livestock with lush grass pastures summer. The first Provençal shepherds already put in a park their animals for the night five thousand years ago, and two millennia ago, sheep were built by Roman settlers in the city of Arles. These are long buildings reflect the importance of the pastoral activity in the Crau (Badan *et al.*, 1995). This practice is still in activity, and requires sheep that have the ability to live on diverse backgrounds (more or less arid grasslands, bushy areas, hilly lawns in pastures), resulted after a long genetic selection. Since the 1970s, the *Coussoul*'s ecological and heritage value has been recognized, and culminated by in the establishment of the *Réserve Naturelle Nationale des Coussouls*

*de Crau* in 2001 (<http://www.reserve-crau.org/>). But this does not stop the development of projects that destabilize this original ecosystem.

## 1.2. The Irrigated Crau (the Crau hay)

In the northern part of the plain, through the creation of the canal of Craponne at the end of the sixteenth century, the Crau landscape has undergone a radical transformation from Coussoul to an irrigated meadow. The Provençal engineer Adam de Craponne (1526-1576) had the idea to divert some of the water from the Durance to bring through the Crau in Arles (where excess is discharged into the Rhone River). Initially arranged for the hydraulic industry (flour mill), water began to flow in the canal in 1559. Gradually, the water has been used for regular irrigation of grasslands. In the 1670s, the Ravel brothers have established a network of pipes for irrigation by micro channels (“rigole”). A deviation of the Craponne Chanel was then built in the twentieth century: the Haute-Crau irrigation network. This network consists of twenty km long pipes fully concreted, and it serves an agricultural area upstream from that served by the Craponne Chanel. This channel network has gradually expanded with the development of a dense network of small irrigation ditches. Since the 1960s and the hydro-electric development of the Durance Valley, including the building of the Serre-Ponçon dam in the French Alps, has ensured regular resources throughout the summer season. The waters of the Durance river charged with silt have clogged the stony giving the actual green landscape. Gradually, a soil has been created, allowing the development of a meadow, which is mowing three times a year and is watered every ten days by total submersion of the plot, between April and September. Each cut grass is left on the fields to dry before being packaged and sold. Autumn 4th regrowth is grazed by sheep returning from summer pastures. 12 000 ha of hay Crau (allow the production of grassland Crau hay with exceptional nutritional quality) have gradually substituted the Coussoul.

Larcena (1995) studied the evolution of Crau landscapes based on satellite images between 1975 and 1994, as well as on a landscape approach, he concluded that “*three types of land have particularly developed since 1975 and strongly contribute to the transformation of landscapes: orchards, greenhouses, urbanization*”. This trend, which is not specific to the Crau, has increased in recent years and competes with the practice of growing hay that allows groundwater recharge and a limited use external inputs compared to other modes of farming practices.

## 2. An original and fragile groundwater

Under the plain of Crau, the groundwater estimated at 55 million m<sup>3</sup>, was classified as “patrimonial interest” within the Master Plan and Water Management of the Rhone-Mediterranean Basin (SDAGE in French). This groundwater is fed to 2/3 by gravity irrigation of 12 000 ha grassland Crau for hay, the rest being sourced mainly from rainfall (BRGM, 1996). Even though water is present almost everywhere in the basement of the Crau, its level and quality are variable in time and space. The management of this vulnerable aquifer, allowing its sustainability and quality, raises the question of its management by several economic agents with different interests.

### 2.1. A fragile aquifer

The average annual volume of irrigation water brought to a field Crau between 15 000 and 25 000 m<sup>3</sup>/ha/year and the average annual volume brought to the plain by irrigation of these grasslands is estimated at 1 700 m<sup>3</sup> / ha / year with values ranging from 1 100 to 3 800 depending on the characteristics of grassland (Saos *et al.*, 2006). On average, according to SYMCRAU data (cf. § 2.2), 80 million m<sup>3</sup> are taken annually from the Crau for agricultural activities (32 million m<sup>3</sup>/year), domestic use (30 million m<sup>3</sup>/year), industrial activities (18 million m<sup>3</sup>/year).

Although the quantitative and qualitative status of the body of water remains generally good (SDAGE, 2009), but its vulnerability is high due to its shallow depth and to the high permeability of the soil.

The Crau is dominated by industrial arboriculture and an intensive gardening that use a lot of inputs and pesticides. In the South, it suffered from the presence of atmospheric pollution of the Industrial Port Area of Fos developed forty years ago - and which solids can settle on the surface. The groundwater can also be directly contaminated by pipelines crossing. Thus, during the summer of 2000, a ruptured pipeline of the

Corporation Southern European Pipeline (EDS) in the Crau natural reserve caused the pollution of 5ha by the leakage of 4 000 m<sup>3</sup> of oil. To the east of the Crau, a multimodal platform, an Area of Economic Area and Military activities around the base of de the town of Istres, including ammunition depots, forms another potential source of pollution. More punctually, road bypasses of towns and motorway links also impact daily and sometimes accidentally the environment groundwater at the edge of the pond. The Entressen discharge is at the origin of Cl, NO<sub>3</sub> and SO<sub>4</sub> infiltration related to the garbage dump of Marseille city (largest open dump in Europe which ran from 1912 to March 2010) (SDAGE-RMC, 1995).

## 2.2. The water management of the Crau: a territorial issue to rethink

Economic agents in connection with the water in the Crau are farmers, residents but also municipalities, industrial, military and *Electricité de France (EDF)*. EDF manager of an important channel between the Durance and the sea is today is the first water surface area Crau provider; it is also for groundwater but indirectly to the extent that the aquifer is mainly fed by the water of the Durance, carried in the EDF canal which supplies the upstream Crau channel (Martin, 2008).

But the economic and social context of the region has changed. In the 1990s, with the economic crisis in Italy, largest buyer of Crau grass, the price fell and measures of Community Aid to the Environment have been implemented in 1993 and 1994 to assist the profession. Then, a few years later, other measures followed to support the production of hay. These measures have had the effect of perpetuating the recharge of the aquifer by surface irrigation but does not fully satisfies farmers, who are still suffering from poor economic performance that encourages some to abandon this activity and to promote the sale of land for other activities not requiring the regular flooding of the soil. During this period, soil sealing (multimodal platforms, multiplication of new roads ...) already engaged in the 1970s, with the development of industrial port complex of Fos.

The multiplication of quantitative and qualitative resource pressures are behind the creation of a joint union and management studies of the groundwater Crau in 2004, SYMCRAU, a union which member of municipalities and other organisms (*Syndicat d'Agglomération Nouvelle - Ouest Provence*, Chambers of Commerce and Industry of Arles and Marseilles, Chamber of Agriculture) and also, but in a consultative manner, (the Committee Crau hay, the Conservatory Ecosystem Provence, the Maritime and Industrial Group of the Gulf of Fos, the Departmental Federation of Hydraulic Structures and the *Port Autonome de Marseille*). The question that is raised is the definition of an optimal management policy of the groundwater in the Crau to guarantee its continuity and quality. This sheet shows the reconfiguration of modes of governance and of the ownership of regulatory tool consultation by local actors. The SYMCRAU mission is now to conduct studies to define a way of managing this groundwater Crau with the idea of developing a groundwater contract to improve the management of this unique resource.

## CONCLUSION

Groundwater of the Crau is mainly due to the summer regular submersion (2/3) since the eighteenth century in a part of the plain. This groundwater, mainly anthropogenic, has for recent decades led to the development of an efficient and low emitting farming. Today it is affected by various sources of pollution related to modern economic activities (arboriculture, gardening, urban planning, roads ...) which are practiced at the expense of hay meadows that recharge groundwater. Although, if the level of degradation is not yet as shouting as in other regions in the word, the question of the qualitative and quantitative sustainable protection of the aquifer forms an important territorial issue

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