PRESENT STATE OF WATER ENVIRONMENTS IN SPAIN

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I. INTRODUCCIÓN

Water environments are unique resources by their functions in Nature and by their utilities and services for human groups, and are therefore a valuable wealth. Specifically, lakes, rivers, marine and underground water are territorial resources that bring ecological diversity, shape landscapes and, very often, are used by Man in his activities (Martín Montalvo, 1996). Water environments are not stable in quantitative and/or qualitative terms, but variable and open to the influence of local and regional natural systems and to the increasing impacts by man over this renewable resource.

This article analyses the recent evolution of water environments (in concrete along the 20th century) and its present hydric-geomorphological state. In general, they have been altered direct or indirectly by the increased social demand, by the deep territorial changes and by the little value given to this natural and cultural wealth. A prognosis of hydric-environmental changes and of its present state requires a constant reference to its management by public authorities and the development of public policies.

II. MANAGEMENT OF WATER AND ITS ENVIRONMENTS

In Spain, public policies and private enterprise have developed many hydraulic actions to meet growing urban, tourist and industrial needs, to expand irrigated lands and to increase hydroelectrical production, which have triggered environmental adjustments, simplifications or metamorphosis in rivers, aquifers or wetlands and their systems.

There are three phases in this long cycle of increased water uses. From early 20th century until the Spanish Civil War, public policy was marked by re-generationist projects. It was a time for geographical inspections and for hydraulic applications to hydroelectric dams, reservoirs and hyper-reservoirs, for implementing and exploiting river flow network and, above all, for planning (Gasset Plan and Lorenzo Pardo's Plan). The second phase, from the Civil War to the '70s, started with a standstill of hydraulic works, followed by their intensification. However, there were as well very little innovation in underground water exploitation or in sewage depuration. In the third phase, from the '70s on, hydraulic works were kept up in general and the Tagus-Segura rivers transfer was carried out (Díaz-Marta, 1996). The same goal of use intensification was maintained in the National Hydrologic Plans of 1993 and 2001.

For some years now, however, planning has also included a complete management of water and, recently, is giving a natural and cultural value to wetlands, fluvial corridors and delta plains, to environmental restoration, to ecological water flows, etc. This new approach is due, among other factors, to some international covenants, to European Directives and to the new public conception of Nature protection set by the Spanish Constitution of 1978 (Mateu, 2007).

II.1. Planning and hydraulic works

The hydraulic policy for water regulation and/or exploitation with productive goals was based on different hydraulic (and not hydrological) plans, and it was continuously mantained throughout the 20th century in Spain. Results were outstanding in social, economic and territorial terms, but they had large environmental costs, with flooded valleys, denatured banks, dried-up wetlands, contaminated basins, transitional areas in recession and a coastal system in crisis.

For regenerationist politics, water was richness and irrigation was the object of plans, congresses and projects. The intention of the *General Plan of Irrigation Channels and Reservoirs* of 1902 –also called Plan Gasset, drawn by the Civil Engineers Corps- was to regulate the flow of every tributary river by small dams to hold the Winter discharge until Summer when it was used in farming or the industry. This Plan was in force until 1926 and it enclosed over two hundred proposals; its results however, were few and slow due to its own limitations, to a messy management and some persistent financial difficulties (Ortega, 1995).

The *National Plan of Hydraulic Works* of 1933 –also called Lorenzo Pardo's Plan- is an outstanding milestone of hydraulic regenerative policy. On one side, the author integrated into the Plan proposals forwarded by different basin bodies and his own experiences managing the Ebro river basin (the so called hyper-reservoirs). On the other, the Plan foresaw transferring water from the Tagus source to the Mediterranean façade to meet national interest, inner consumption and external demand needs (Romero, 1995). The plan failed in its discussion, but the later *General Plan of Public Works* (1940) of Franco's first government had similar criteria that were to come real some years later.

In 1955, reservoirs amounted to 8,000 hm^3 of capacity. From 1956 to 1965, damming capacity was increased much until it almos reached 25,000 hm^3. In 1970 –when the *developmental* policies were in force-, capacity had exceeded 36,500 hm^3. Later on, the political and economical crisis slowed down the pace although it has reactivated and nowadays, reservoirs are over 55,000 hm^3 of capacity.

Next to reservoirs, we have to mention the Tagus-Segura transfer (Martínez, 2001), a 275-km-long pipe from the Bolarque reservoir to the Talave reservoir. Works were started in 1971 and they were justified by the larger profitability of Mediterranean irrigated lands, as an alternate to emigration, as an action that corrected Nature to gain profits from resources that were going to get lost in the sea. At this moment, balance is far from the estimations because the transferred resources have been under the legal maximum and, above all, because the irrigated lands in the Segura basin were increased beyond the amount thought of at first (they have taken over steppes and salty areas, salty marshes have sweetened while the Segura river is getting saltier, alteration of the Menor Sea, etc.).

The Water Act of 1985 required an hydrological planning. In this sense, the *Libro Blanco del Agua* (Water White Book) (1998) modified the traditional planning approaches integrating water environment: *demand, managing and conservation* strategies. In words of P. Arrojo (2003), the book ought to be classifed as a good transitional document, although it finally decided to give priority to strategies, with more than one hundred of new large reservoirs and the transfer of 1050 hm^3 from the Ebro river to the Mediterranean coast.

The *National Hydrological Plan* (2001) –more than fifteen years after the Water Act of 1985 made it mandatory- enclosed the Northern and Southern Ebro water transfers, a decision that caused a deep social fracture and opposite territorial positions. At the end, the transfer was revoked by the new Parliament majority on June 2004.

On April 2005, the Spanish Parliament passed a new *National Hydrological Plan* which, roughly, modified the 2001 Plan and replaced the Ebro Transfer by the *A.G.U.A.* (Water Management and Usage Actions) Programme. This programme is to undertake more than one hundred actions -among them the building of new desalinizing plants- that will bring a total amount of 1,063 hm^3 of water to Mediterranean basins, an amount slightly higher than the amount foreseen for the Ebro Transfer. In this sense, the Ministry of Environment is drawing a Report on Environmental Sustainability (Informe sobre la Sostenibilidad Ambiental) of Urgent actions of the AG.U.A. Programme. Said report is explicitly taking into account *a demand restriction* at a *long term*, which is not easily compatible with any action *urgency*. All of this is clear evidence that, although we are shifting -as provided for in any European guidelines- towards more environmental conservationist postures, water management and planning tasks are not solved yet and they keep generating big conflicts.

II.2. Legal framework

Liberal law-makers divided natural systems in isolated components (mountains, water, mines, etc.) and entrusted their sectorial management to the new Administration technical corps. In general, they intended to remove obstacles and to promote a productive use of natural resources. In this sense, they legally differentiated between surface waters (State owned and managed by civil engineers) and underground waters (privately owned and managed by mining engineers). Below there appear some of the most outstanding milestones of water acts.

The Ley de Aguas (Water Act) of 1879 –that continued the line set by the act of 1866 and was in force until early 1986- regulated the general framework for terrestrial water, hydraulic works and subsidies, associations of irrigated-land owners, water exploitation and concessions, etc. This basic law was followed by many decrees, orders and regulations, some of which had a special effect on water environments. Thus the so-called Cambó Act (1918) promoted drainage of many wetlands and their transformation into farm land. Besides, the Urgent Help Act of June 1911 divided per municipalities the work projects against river floods and prevented a supra-municipal approach to river dynamics.

Many years later, this sectorial legislation of natural resources was obsolete and did not fit in the new international context. The agreements reached at the Stockholm Conference (1972) and other similar agreements (Ramsar, etc.) placed environmental problems, the limits of natural resources or planning of protected natural spaces on the agenda of public policy. These guidelines are followed by the environmental principles of the Spanish Constitution of 1978, that were to found the future public policy and the development of any Nature Protection and natural resources managing laws.

Another legal milestone was the Water Act of 1985. It recognizes for the first time that water is a renewable unitary resource. Therefore, it included any underground waters within the public control, and took away the ownership right (given by the Act of 1879) from whoever had discovered them. Although water was still linked to the regenerationist idea of a wealth component, the 1985 Act reinforced the public character of waters, provided for a mandatory hydrological planning, cared for water quality and included hydric-environmental approaches.

Spain, since its incorporation to the European Union, accepted adjusting its law to objects set by European directives. In this sense the European Water Framework Directive of 2000 (Arrojo-Del Moral, 2003) –already set over the Water Act in force-sets that "the water is not a trading good as others resources are, but a patrimony that must be protected, defended and managed as such". The Directive refers to aquatic eco-systems many times, and it demands a prudent and reasonable use taking into account every available scientific and technical data. The Directive proposes making programmes adapted to local and regional conditions. In every case, an efficient and consequent water policy must take into account the vulnerability of aquatic eco-systems. The application of the European Framework Directive is the basis from which it is possible to prevent any additional damages to water environment as well as to protect and improve its situation (Grande *et al*., 2001).

II.3. Water Authorities and Water Environment Administration

Versus a sectorial management that divided water according to its human uses (supplies, irrigation, hydroelectrical production, etc.) or to compartimented reservoirs (superficial waters, underground waters, marine waters, etc.), the Framework Directive is using the *hydrographical basin* –an ecological, hydrological and hydrogeomorphological system- as the basic unit for managing, planning and applying protection and sustainable measures on water.

This approach is also followed in Spain, where watersheds –since 1865— have delimited the land unit for technical services of Water Authorities. However, said hydrographic units –nowadays governed by a basin authority— do not meet provincial or municipal demarcations, or recently autonomous community limits. This territorial singularity of water authorities is or can be a framework for inter-territorial cooperation or tension, with environmental impacts that may reach aquatic eco-systems.

The original administrative organisation in *Confederaciones Sindicales Hidrográficas* (administrative and managing agencies for each river hydrographic basin) (1926-1932) was to promote building hydraulic works and the integrated and joint explotiation of every hydrographic basin, with the help of the concerned people (Fanlo, 2007). Specifically, the *Confederación Hidrográfica del Río Ebro* developed an ambitious programme (Frutos, 1995) that modified the regional structure and encouraged outstanding ecological and social-economic changes. However, the Agencies' initial nature was soon degraded when users lost their representative and, since 1958, there were turned into two main bodies: the *Comisaría de Aguas* (Water Commissariat) (on water) – *Confederaciones Hidrográficas* (Administrative and Managing Hydrographic Agencies) (works), until the 1985 Water Act.

The Spanish Constitution of 1978 grants the State the full exclusive competence on "law-making, planning and concession of hydraulic resources and exploitation when water flows through more than one Autonomous Community". The *Tribunal Constitucional* (Constitutional Court) read that these competences are exercised over the hydrographic basin. In other words, the State has the exclusive competence over the so-called inter-community basins that exceed the territorial scope of one autonomous community; on the other side, any autonomous community is to control the so-called intra-community basins.

III. DYNAMICS OF WATER ENVIRONMENTS

Water is an element essential for life and basically dynamic, as its efficiency is based on its mobility. The fact that it is the only mole appearing naturally in the three states (solid, líquid and gas) results, through energy exchange, in one of the main dynamic factors. The other engine of movement is gravity. The flow of water from some reservoirs to other ones in the world, although it only affects 1% of the total volumen, is significant for the development and conservation of natural systems.

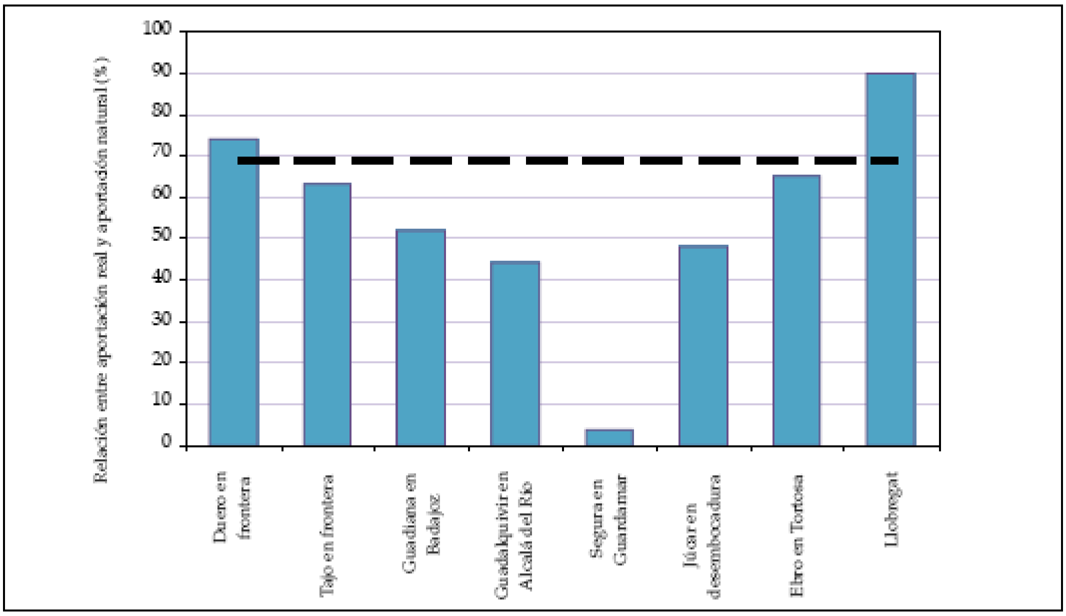
Water environments are shaped by the interaction of hydrology and natural systems under complex conditions of dynamic balance. The exchange of water, energy, sediments and nutrients are constantly adjusting in order to reach the maximum efficiency and ecological wealth.

However, said natural balance is getting more and more precarious as a consequence of human actions. Man acts on natural cycles, altering water distribution in reservoirs, the permanence time in each of them and the flow process from one to another. All of this generates problems in the water available to each natural system in a given moment.

Among the most relevant actions of late decades, it is to be pointed out enormous land transformations, derived from crops extension (50 % of the Spanish land is farmed), and from an increase of urban development (it has increased 30% from 1991 to 2001).

In relation to human activities, the concepts of *renewable water*, understood as the superficial and underground resources renewed each year by rains, and of *extracted water*, as the water taken by man for its activities out of the supplying sources, are relevant. In absolute terms, whenever extracted water exceeds renewable water (which in our country ranges around 111 km^3), the natural dynamics of water systems is upset badly. Although it does not reach the general hydric balance, any man action on the water cycle generates imbalances that, in the case of Spain, have been very intense, specially in the second half of last century. Figure 2.1 is an example of man influence over the natural cycle. It shows, for some important rivers, the quotient between present average flow, as a *charged system*, and the flow without any human action, the *natural system*. It is outstanding the case of the Segura river, where only 4% of the natural water gets to the sea.

Figure 1. Relation between actual contribution and natural contribution for different Spanish rivers



Source: *Libro Blanco del Agua*, 1998

Although the most relevant effect is a decrease of water flows from a quantitative point of view, the progressive decay of water quality, the unbalance of basin erosion-carrying-sedimentation processes, the disconnection between river system elements, landscape and bio-geographical degradation, etc. are also alarming.

Water environment dynamics in Spain is linked, therefore, to human action. Among the most relevant actions of late decades, it is to be pointed out enormous land transformations, derived from crops extension (50 % of the Spanish land is farmed), and from an increase of urban development (it has increased 30% from 1991 to 2001 according to INE). All these facts imply important changes in water cycle processes, specially those related to run-off, apart from a high increase of water demand that, very often, has been met by building large hydraulic infrastructures. According to the Ministry for Environment (2006) nowadays there are over one thousand large dams, with a total storage capacity far above 54,000 hm^3 (56,000 hm^3 if the reservoirs in construction are included).

Constant human actions on water environments have shaped a setting where most rivers are regulated, dams are essential and have developed their own eco-systems, wetlands have lost their area and bio-diveristy by continuous drainage, and where underground waters are increasingly degradated. Only in recent years this trend seems to be shifting, thanks to the European Framework Directive, towards much more sustainable and environment-friendly positions. At a state-wide scale, new river restoration strategies (AGUA Programme) have been implemented, which intend to regulate actions to recover the good ecological and functional state of rivers. At the demarcation-level scale, similar initiatives are also seen: the Confederación Hidrológica del Norte has started to follow-up projects on dams exploitation concessions intending to pull down any obsolete infrastructures; in Catalonia, the Catalonian Water Agency is working hard to recover its river environments; in the Guadalquivir river, water-saving measures are increased in relation to farming; etc. In short, in recent years there is a tendency to return Nature to water environments and to recover their environmental, patrimonial and cultural values, versus the basic developmental ideas that prevailed in the hydraulic policy of the past century.

III.1. River environments

River environments amount to 0.001% of the water in the planet (14,000 km^3), after oceans, aquifers, glaciars, lakes and grounds. In Spain, according to the *Libro Blanco del Agua* (1998), the total amount of run-off or useful rains is 220 mm, which means a run-off quotient of 32% (organized in two watersheds: the Athlantic watershed receives 75% of yearly contributions, and the Mediterranean watershed the remaining 25%). They are not the largest cycle reservoirs but as they are the most dynamic, they are as well the most relevant.

They are complex morphological-generating instruments and their functions adjust continuously to the fluctuating mass and energy conditions of the system through erosion, transportation and sedimentation processes. Rivers play an important role as carriers of water, sediments, nutrients and living beings and, consequently, are able to articulate and structurate land. They are true geo-morphological, ecological, landscape and bio-climatic corridors, and the wealth and diversity of natural systems is in their mobility (Malavoi *et al.*, 1998).

Fluvial dynamics generates different environments that follow each other along the river. Richness is larger the wider and more diversified is the basin. Some instances are: the Ebro river (85,997 km^2) that runs through Cantabrian, Pyreenean and Mediterranean land; the Guadalquivir river (57,421 km^2) that, apart from being a Betica depression, combines the Athlantic ocean effect with high mountain environments; or the Tagus river (1,202 km-long) that runs through different inlad morpho-climatic areas.

At a smaller scale, fluvial systems articulate in basins, watersheds and drainage networks that shape, from headwaters to mouth, different hydric geomorphological and ecological environments. In general, they are differentiated in headwaters, middle basin and flood plain environments.

Erosion processes are dominant in headwaters environments, and they shape landscapes full of canyons, gorges, surgences and waterfalls. They usually are well conserved because they are in montainous areas where human occupation is not so intense as it is in low basins. They some times become State Parks as, for instance, the Parks of Alto Tajo, in Castilla La Mancha; of Ordesa and of Monte Perdido, in Aragón; of Aigüestortes and of Estany de Sant Maurici, in Catalonia, or of Hoces del Cabriel, in between Castilla la Mancha and the Community of Valencia. These environments present, along river beds, plenty of micro-habitats promoting bio-diversity and ecological wealth. Besides, their environmental quality attract tourist demand related, above all, to Nature activities, which within the appropriate legal framework increases their potential for their sustainable exploitation.

Sediment carrying and re-mobilization processes prevail in middle basin environments. They are often tectonical generated intra-mountain corridors, with processes depending on water flow; alluvial piedmonts, cones, terraces and fans are most frequent landforms. Some times, man takes advantage of these sections and closes them with dams to hold water. They present an intermediate conservation condition, due to the imbalaces generated by hydraulic infrastructures, on one side, and on the other by dry-crop farming that has removed natural plant species and denaturalized river bank forests.

However, lower basin environments show the largest man-generated alterations. From a natural point of view, flood plains are the most dynamic geomorphical elements of fluvial systems and are subject continuously to processes of flow-load adjustment (Rosselló, 1989), although sedimentation mechanisms prevail in them. They are the river flooding area and they act as a water and sediments reservoir, cutting flood peaks (Dunne and Leopold, 1978). They also act as sedimentation basins, responsible of renewing ground fertility and recharging alluvial aquifers.

Flood plains and their corresponding channels are complementary and inseparable, and they make an hydrogeomorphological unit. The widest ecological exchanges take place during floods, when channel connections to every bank sub-systems (abandoned meanders, dead branches, sideline depressions, etc.) are recovered. Flood plains productivity is thus regenerated by new biota, sediments, organic matter and nutrients (Junk *et al.*, 1989; Tockner, *2000*). Some authors (Ollero *et al.*, 2007) talk even about "ecological floods", as a concept to take into account in relation to the management of regulated rivers, beyond environmental flows.

Lower river basins have stood the largest human pressure derived, basically, from the large urban development of last decades. In Spain, from 1987 to 2000, 12% of the surface of rivers and their natural beds have been reduced (around 7,508 ha) as a consequence of urban development processes (Lastra *et al*., 2007). As a consequence of their going through cities, fluvial corridors have become mono-functional channels restrained to their minimum area in the middle of buildings and streets (when they are not covered up) and reduced to simple drainpipes. Instances are the Segura river in Murcia, the Genil river through Granada, the Llobregat river downstream Martorell, the Francolí river in Montblanc or the lower Arga (Ollero *et al*, 2007).

Apart from any direct actions on river beds, river environments are also debased by industry and energy-production related spills. Other more conservationist activities such as farming make also a large impact through irrigation, generating effluents, spills and refuse, with the peculiarity that all of them spread over very large spaces (Gómez Orea *et al.*, 2007). All these actions decrease water quality, reduce eco-systems biological diversity and promote a proliferation of invading species, in reservoirs specially. Instances of seriously-contaminated river environments are found in Barcelona on the Besós river, in Murcia on the Segura river, in Huelva on the Tinto river or in Sevilla on the Gaurdamiar river. In relation to problems derived from a sucession of barrages and hydroelectric dams, the most troubled area is the Ebro river.

In short, river environments are increasingly weaker in relation to man's capacity to change the land. Rivers are made stable by flow regulations, channelling, meanders short-cutting, etc., while their waters are chemically contaminated and their biological diversity is altered and reduced. However, fluvial dynamics is the key not only for fluvial systems hydrogeomorphological working but also for their ecological, scenic and environmental values. Rivers need to move and to create life. Any fluvial dynamics re-activation translates into the re-activation of its ecological dynamics (Malavoi *et al.*, 1998). Therefore, to conserve a river implies insuring its hydrogeomorphological dynamics, the last insurance for the protection of each and every one of the system elements and their relations (Ollero, 2003).

This conservationist approach prevails lately in relation to fluvial restoration and has led to the term "space for fluvial mobility", at the proposal of the working table on *Alteraciones Geomorfológicas de los Ríos (River Geomorphological Alterations)* (Ollero *et al.*, 2007*)*, within the State Plan for River Restoration (A.G.U.A Programme), at the Madrid meeting on September 2007. Said term defines "a space, wide enough with time-variable boundaries, where a river can function, erode, deposit sediments and flood”, without detriment to the performance of human activities compatible with environmental purposes, as proposed by Kondolf *et al.* (2003). The idea is to recover Nature in river environments thanks to a new Man-Environment relation, where every river section and not just heawaters are in good conservation conditions.

III.2. Wetlands

Wetlands are transitional systems between terrestrial and aquatic environments, either if the former are continental (rivers and lakes) or marines. They are, therefore, frontier systems between the terrestrial and the aquatic means (Casado y Montes, 1995). Wetlands can be, also, *zonal*, a fringe around an aquatic means, or *azonal*, a wet unit within a dry environment.

Although they have many different names: bogs, wetlands, marshes, salt marshes, quagmires, pools, etc., all of them have water as common element, either over the ground, or as shallow constantly water-saturated ground (Custodio, 1987), plus hydric-morphological soils and hydrophilic vegetation. From an ecological approach, wetlands are very interesting as they are highly life-creating systems conditioned by water salinity, turbiness and permanence (Alonso, 1987). They are true ecological enclaves, and their relevance extends beyond any local eco-systems as migratory fauna find in them food, rest and shelter.

Water presence is, undoubtly, the essential factor of these environments and it conditions their own existance. In reason of their hydrological working, Custodio (1987) differentiates three categories of wetlands:

a) **Wetlands associated to regional underground-water systems**. Thanks to aquifers they have a constant supply of fresh water, with little seasonal or inter-yearly variations. They are in large or middle size sedimentary basins, with large flat areas, lower in comparison. They may have or not an outward drainage. If water supply is large enough, there may be a permanent river draining the excess of water (such are the cases of the Ojos del Guadiana river in relation to Tablas de Daimiel or of the Terri river with respect of Estany de Banyoles). When the supply is little, as in the case of the peripheric area of Doñana, there are no outlets although there appear boggy communities supplied by the wet ground. Instances are in Tablas de Daimiel, the periphery of the State Park of Doñana, Bahía de Alcudia (Mallorca) or the fringe areas of Estany de Banyoles (Gerona).

b) **Wetlands due to the discharge of local underground-systems**. They present important seasonal or inter-yearly variations due to aquifers' scarce regulating capacity. It means that marshes may differ from time to time, or even disappear in draught times. Many Spanish coastal wetlands are in this category, for instance, the wetlands in Pals (Gerona), Oropesa (Castellón), South of Gran Canarias, etc., and they are today almost disappeared.

c) **Wetlands supplied by surface water**. They present a large seasonal or inter-yearly variation. They are associated to areas flooded periodically by rivers or springs, where surface drainage is deficient (flat or inlet zones) and infiltration is minimum (either because soils are clayey or because the water table is close to the surface). A good instance is in the central zone of Marismas del Guadalquivir.

In truth, **natural boggy systems are mixed** and they resemble one or any other category according to season and their conditions. Thus, for example, the "aiguamolls" of l'Empordà (Gerona) are systems supplied by regional and local underground systems, with relevant contributions of surface waters and marine influence. Marismas of the Guadalquivir river depend, mostly, on surface water, but the high water table keeps ground wetness in between floods while local supplies keep wells and permanent water places. Tablas de Daimiel are due to a regional water table and, at the same time, to river floods.

In short, boggy systems are very dynamic both in time and in space. The same area, depending on time differences of physical and biotical conditions of the environment, may present properties that range from a deep-water environment to a terrestrial environment (going through every boggy and crypto-humidity state). At the same time, different wetland categories may appear simultaneously in association to complex systems, and their spatial expression is a mosaic of environments that changes its composition and distribution through time (Casado and Montes, 1995).

The largest changes, however, are not due to natural causes but to man actions. Historically, wetlands have never been valued. They have always thought to be dangerous and unhealthy areas that ought to be “drained” for the benefit of the nearby populations or to gain new farm land (Custodio, 1987). As a result in the last 200 years they have lost 60 % of their surface (Casado and Montes, 1995), from 280,000 ha to present 114,000 ha. (in truth losses have been larger as the estimations of the original boggy surface point to 500,000 hectareas).

Man actions on Iberian wetlands have followed two different patterns (Casado and Montes, 1995). A more environment-friendly and conservationist process is based on wetlands partial transformation that, although having productive purposes, speaks of an interaction of Nature and Culture. Some instances are: saltworks (that go back to Roman times), rice paddies (dating from the Middle Ages and much extended on the 18th century), soda manufacturing from saltwort plants, hunting, shellfish fishing, pastures, medicinal baths, mud extraction, legends and traditions. The other pattern is much more agressive and it is based on ground draining, ploughing and farming. One of the first state-sponsored examples is the draining of Villena's (Alicante) small lake from 1784 to 1805.

In the 19th century there were many more or less successful draining attempts, helped by the so-called Cambó Act of 1918 (revoked by the Water Act of 1985), the purpose of which was to encourage drainage of small lakes, salt marshes and bogs with incentives. It was, however, the developmentist farming policy followed in the '50s, '60s and '70s which has contributed the most to destroy Spanish wetlands: the small lakes of Antela (24 km^2) in Orense, of La Nava (22 km^2) in Palencia and of La Janda (40 km^2) in Cádiz. Nowadays, the Water Act protects wetlands but their destruction goes on because of the overexploitation of underground waters (Libro Blanco del Agua, 1998).

Casado and Montes (1995) have studied the destruction process of wetlands in Spain and they have made five large groups:

a) Karst **Mountain systems** are in an acceptable conservation state because their physical environment presents many difficulties to their transformation. Their main alterations derive from water degradation sometimes caused by a high tourist impact, as in Lagunas de Ruidera. In high mountain areas, the most relevant factor for degradation is linked to the proliferation of ski resorts, as in the small lakes of Peñalara (in the Guadarrama range) affected by the Valcotos resort, or in the Ibón de los Asnos, in the Pyreenees in Huesca, affected by the Panticosa resort.

b) **Inland wetlands** are in the sedimentary basins of both Castillas, the Ebro river depression and Andalucía. Their state is worse because they are shallow wetlands on flat good farming lands. There are only 4,800 ha versus a total estimation of 14,800 ha of fresh water systems. Salty wetlands are better conserved because they are not so suitable for farming. However, the salty wetlands in Monegros and Alcañiz are affected although farm results do not justify their environmental impact or the investments made.

c) **Flood plains** are basically located in La Mancha region. They present the worst problems due to draining, channelling and over-exploitation of underground waters. They are just 20% of their original extension (3,200 ha from the original 15,700 ha), including Tablas de Daimiel which are supplied with external water contributions and have become a man-supplied eco-system.

d) **Coastal wetlands**. In absolute terms they have suffered the largest losses of boggy surface to draining, crops, urban development, rubbish and industrial waste. More than 140,000 ha have been destroyed and only 98,000 ha remain of the 240,000 ha of wetland existing a century ago. They usually are large units (the Marshes on the Guadalquivir river are half of the total boggy surface in the Peninsula) and have a large environmental value. Human actions have transformed them into rice paddies -as in the

Eastern coast-, where a man-made seasonal flooding has given place to alternate aquatic habitats. Among their new problems is the fast proliferation of marine fish-farming or coastal aquaculture, which are causing many impacts on Andalucian marshes and some areas along the Cantabrian coast.

Since the Water Act was passed in 1985, the perception and legal treatment of wetlands have changed much. The state owns waters and wetlands and every one of them is protected for environmental reasons. In Spain, in the last 20 years, from the former 7 protected wetlands there are more than 150 (Libro Blanco del Agua, 1998) as provided for the acts on Waters, Coasts and Natural Spaces Conservation. Nowadays, the European Union, through their Framework Programme (Water Framework Directive and Habitat Directive, among others), has renewed the interest for wetlands protection. There is much still to be done, however, specially when putting the law into practice. Unfortunately there are many instances of false recoveries and doubtful digger-executed restoring plans that, pretending to re-create the natural habitat, have destroyed the environment forever.

III.3. Underground waters

To talk about underground waters is to talk about a part of the water cycle, closely related to fluvial and boggy environments. They can not be understood, therefore, as a separate environment with their own different dynamics, because underground waters are just a large reservoir (the largest in the world except for the oceans) and they are continuously interacting with surface waters. Water table sets wetlands extension, while fluvial-karstic streams and rivers drain underground water excess when they spring on the surface. The connection between beds and aquifers determines river regulation. A constant flow is related to underground outlets, while any subfluvial unconnected beds have an intermittent flow, as in the case of gullies and ravines.

The system of the Banyoles lake is one of the most significant instances of the interconnection of aquifer-wetland-river. It has more than 100 ha of water extension, and it is the second largest lake in Spain (after the lake of Sanabria, in Zamora). It seats over a large karst aquifer the recharging area of which is formed by the calcareous outcrops of Alta Garrotxa, the lake itself and some fluvial beds (the Llierca, Aniol and Burró rivers). The total inlet fed amounts to 84 hm^3 per year (five times the lake volume) and underground circulation is double way: on the surface and at depth. The surface circulation takes place through detritus aquifers located on the first meters, while the circulation at depth refers to an almost-enclosed karstic aquifer reaching to 1000 m deep. This system generates an underground S-E flow that partly emerges in the Fluviá river (De la Orden and Murillo, 2001).

Aquifers generate and support, therefore, a wide range of complex eco-systems, linked to water springs and areas where they interact with surface hydrology. Tablas de Daimiel, Doñana Park, the Ebro's Delta or Valencia's Albufera are instances of their environmental expression. Besides, from the landscape point of view, other landforms exist because of water: caves embellished with stalactites and stalagmites; labyrinth karst, canyons, outcrops, etc. Some instances are Torcal in Antequera, the Ciudad Encantada in Cuenca, or the caves of Nerja (in Málaga), Cristal (in Molinos, Teruel), Agua (in Iznallor, Granada) and Drach (in Mallorca).

Although underground waters have a large environmental value, it is not possible to forget their potentialities as a resource for human activities because man action is what has influenced them the most. According to the *Inventario de Recursos de Agua Subterránea en España* (MOPTMA-MINER-UPC, 1993), a total of 411 hydrogeological units are recorded in Spain (Libro Blanco del Agua, 1998) which amount to a pervious surface of 176,500 km^2. Detritus aquifers are the largest (99,000 km^2) and most of them are under Tertiary depressions, as the basins of the Duero, Tagus or Guadiana rivers. The second ones in relevance are the carbonated aquifers (67,900 km^2); they are usually located under the headwaters of large rivers (Duero, Ebro, Tagus, Guadalquivir, Júcar and Segura), onto which they discharge supplying them with their basic flow. Lastly, volcanic landforms (7,800 km^2) which, save for some enclaves such as Campo de Calatrava, Cabo de Gata or a zone in Olot, are found mostly in the Canary Islands.

In general, over 26% (29,000 hm^3) of the yearly water contribution is from underground waters (percentage that exceeds 70% in demarcations like those of the Júcar or Segura rivers, where it is the most relevant resource). The underground component usually coincides with natural refill of aquifers and it does not mean any problems for natural systems. The conflict appears in relation to their pumping exploitation when the natural refill rate is exceeded.

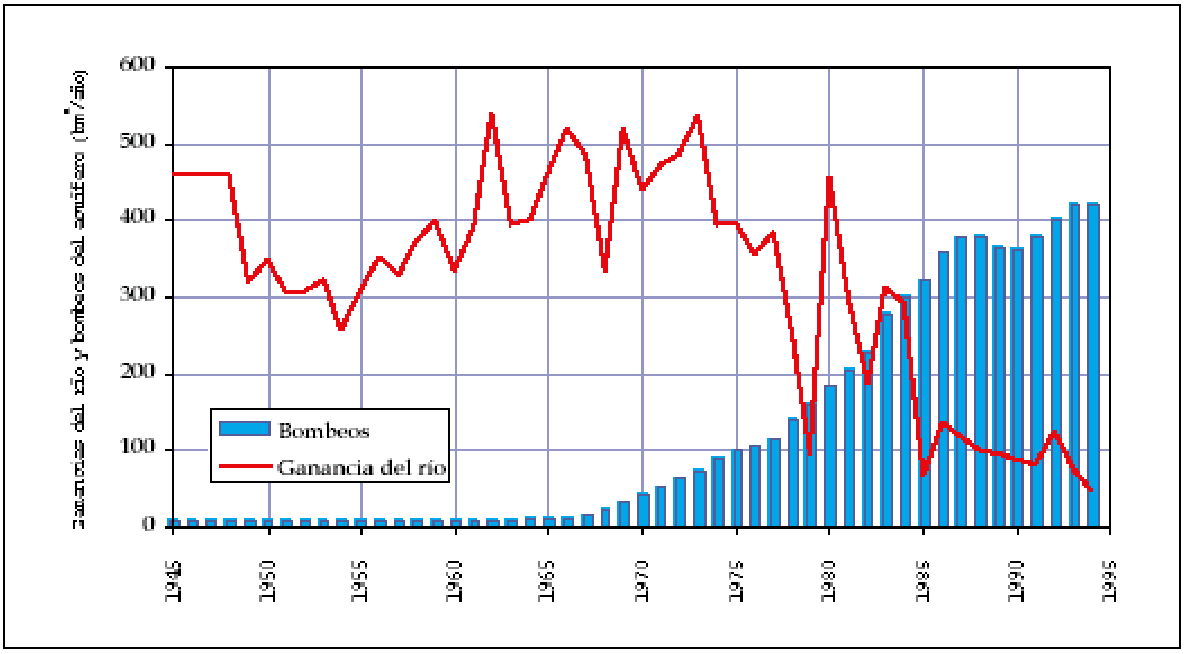
According to ITGE (1993), the water volume stored underground, down to 200 m of depth, is about 125,000 hm3; the largest volumes are under the Júcar basin (79.100 hm^3) and the Duero basin (43.600 hm^3). Man is pumping around 5,500 hm^3/year, that is, 18.5% of the natural refill. Though these numbers are not alarming, the regional distribution of said exploitation points to very conflictive areas such as those of the *Confederaciones* of the Guadiana river (where more than 100% of the refill is pumped); of the Segura river (more than 80%) and of the South (more than 60%). Paradoxically the highest percentage of water pumped in relation to the total amount in Spain is in the Júcar river basin (26%), although it does not imply so many conflicts because the water pumped is just 57.2% of its yearly refill (Libro Blanco del Agua, 1998).

When extraction is larger than refill, over-exploitation becomes a problem. This phenomenum started in the '50s in Spain, continued during the '70s and at present affects more than 20 % of hydro-geological units, specially in the Mediterranean South-East (Murcia, Almería and Alicante) and in inland La Mancha plains (Ciudad Real and Albacete). Aquifer over-exploitation results in different negative impacts: on environment (reducing the size of wetlands and the flow of rivers and streams), on economy (deepening the piezometric table and increasing pumping costs in wells), on quality (increasing salinity) and on geology (causing cave-ins).

Some instances are the decay of Las Tablas de Daimiel and Lagunas de Ruidera caused by the water table fall in the aquifer of Western La Mancha; pumpings carried out in the Llobregat river's Delta or in Plana de Castellón are modifying aquifer-river relations, by which rivers are feeding the aquifer and loosing their flow; or how the exploitation of

Eastern La Mancha aquifer has resulted in an important fall in the Júcar river flow in the last 20 years (Figure 2.2).

Figure 2. Effect of pumpings carried out in La Mancha on the Júcar river flow



Source: *Libro Blanco del Agua*, 1998

Another well-spread problem of coastal aquifers is their salinization due to sea water entry, as it is happening in La Plana-Denia-Gandía, in Alicante and Valencia. In order to shift saline wedges towards the sea, some *man-made refilling* techniques are applied that, in a planned action, introduce water into aquifers. In Spain, the first refilling installations were placed around Barcelona on the alluvial landforms of the Besós and Llobregat rivers. Some wells located in the Llobregat delta have been refilled up to a maximum of 20 hm^3 with the excess water of the water treating plant in Sant Joan d'Espí for several years. Other interesting experiences have taken place in Mallorca, at Llano de Palma; at Boquerón, in the Segura river basin; in the Mazagón river basin, in Huelva, etc. (Libro Blanco del Agua, 1988). Man-made refill, however, is a somewhat difficult to execute technique and it is only applied to very concrete local cases.

Nowadays, most recent actions to preserve underground waters quality point towards the development of some legal instruments leading to a Declaration of Specially-Protected Aquifers (*Declaración de Acuíferos de Protección Especial*). At this moment this instrument priorizes those systems that are an actual or future relevant source for fresh water urban supply; that are the water source of special-interest wetlands, streams or other natural spaces, or that are included in a draught security plan (Libro Blanco del Agua, 1998).

III.4. Some unique environments: Dams and reservoirs

The high irregularity of rains over the pensinsula and the need to maintain surface water resources have turned Spain into a country of dams (over a thousand of them), with a storing capacity of 56,000 hm^3 of water. These infrastructures have been carried in two stages: until 1955 they built an average of 4 dams per year, from that year, the pace got accerelated and some 20 dams were built per year. The largest works were carried out between 1950 and 1979, and the storing capacity was much increased: 98% of this capacity concentrated on 300 reservoirs measuring over 10 hm^3 (Libro Blanco del Agua, 1998). The largest dams, with a capacity over 1,000 hm^3, were located on the *Confederaciones* of rivers: Guadiana (La Serena and Cíjara); Tagus (Alcántara, Buendía and Valdecañas); Duero (Almendra y Ricobayo); Ebro (Mequinenza) and Júcar (Alarcón).

Some unique water environments are thus created by man action but, in some cases, dams have become an essential ecological part, as an alternate to natural lakes and wetlands so much damaged by human activities. In this sense, it must be pointed out that in the Ramsar Covenant on wetlands as internationally relevant water fowl habitats, three Spanish dams are included: Orellana -on the Guadiana river- (figure 2.3), Cordobilla and Malpasillo -both of them on the Genil river-.

Dam building implies important enviromental, ecological, social and economic land effects. The most direct and immediate impact is on the fluvial system the dam is built on. Water holding and basin flooding modify the river hydrogeomorphological dynamics, as well as the existing aquatic and terrestrial eco-systems. The fluvial system turns into a pseudolacustrine one, where sediment accumulation processes prevail, water quality falls due to a rise of eutrophication, bio-diversity goes down and alien species are dominant, etc. In short, from a natural and global point of view, the construction of a dam lowers the environmental quality of an area. Some of the recent strategies for river restoration foresee even the removal of those infrastructures with expired exploitation concessions.

However, in spite of this environmental decay, some positive environmental effects appear depending on the exploitation system. If dam exploitation allows a certain water level stability, wetlands and valuable eco-systems, similar to large lakes, can appear. In some cases new biotopes are created, which become a valid alternate to traditional staying and nesting places for water fowls, even to the point to start new migratory paths (DGOH, 1996). Thus, according to the *Sociedad Española de Ornitología* (Spanish Ornitological Society) (SEO/BirdLife), 35% of the places registered as winter places for birds are reservoirs, specially in Extremadura, Andalucía and Castilla. A notable instance is the Sierra Brava Reservoir, in Zorita (Cáceres), where more than 100,000 Anatidae, 15,000 Sea-gulls, 4,500 Black-tailed Godwits, 8,000 Cranes and more than 2,000 other birds, mainly Coots, Great Crested Grebes and Grebes, were accounted for in Winter 2002 (SEO/BirdLife, 2004).

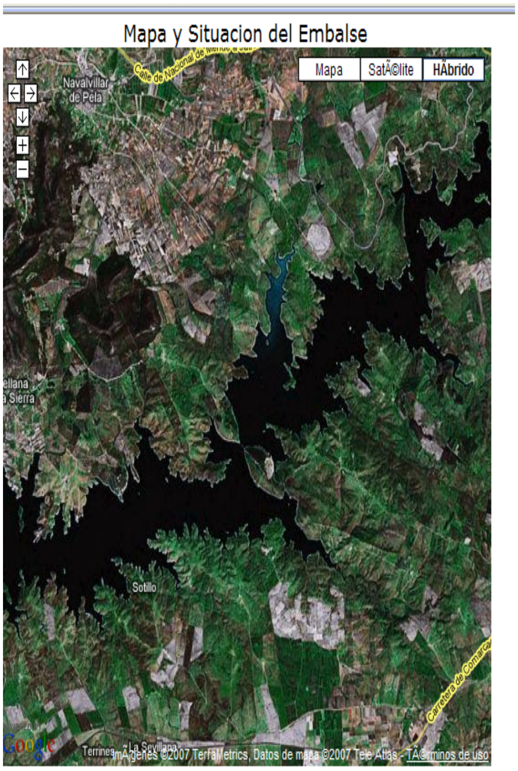
In this line, apart from the Ramsar Covenant dams, there are other ornitologically-revelant dams registered as Fowl Special Protection Zone (*Zona de Especial Protección para las Aves,* (Z.E.P.A. in Spanish), such as the dams of Castronuño (on the Duero river in Valladolid); Navalcan (Guadyerbas river in Toledo); Rosarito (Tiétar river in Toledo); etc. If we include those ZEPAS created nearby a dam, the total area amounts to 225,000 ha. (DGOH, 1996).

Because of the role played by reservoirs as resting and winter place for fowls, actions had been carried in some of them to improve them as a bird habitat: building of islands and barrages to insure a stable level of water, notwitstanding their exploitation. Instances are the Orellana Dam, where three barrages and twenty-seven earth islands have been built from dyke to banks, or the reservoirs of Viñuela, Limonero, La Concepción, Guadarranque and Charco Redondo, all of them in the Confederación del Sur, where the lack of vegetation for nesting has been solved building floating islands.

With respect to water quality, eutrophication and oxygen deficit, these problems have been solved in part in some reservoirs by forced airing programmes. Such is the case in the hypertrophic dam of Zújar (Badajoz), where oxygen concentration has risen from 2 to 9 mg/l in the epilimnion. Other contamination reducing actions are the mass removal of fish from reservoirs, as in Alarcón (in 1994, 300 tons of fish were removed to control the trophic chain from the upper echelons); the application of water renewal techniques through a planned exploitation (as in the case of the water supplying dams of the city of Sevilla); or forest clearance of the basin before it is flooded (DGOH, 1996).

In short, although dams in general are the hydraulic infrastructures having the most negative impact on fluvial systems, it can not be forgotten that some of the largest reservoirs have their own character. They have turned into unique environments, essential as an alternate support for fauna, specially migratory birds. They have developed their own eco-systems and, in those cases of a good environmental conservation, they are an element for rural development, through tourist exploitation. In this sense, versus the aggressive traditional sun-and-beach tourism, large reservoirs have the potential to lead a new soft-core tourist model, more consequent with environment respect and conservation.

Figure 3. Satellite Picture of the Orellana Reservoir



IV. CONCLUSION

Many fluvial corridors, a large number of aquifers and significant wetlands record recent qualitative and quantitative changes in their structure, composition and working. Any regulating and channeling hydraulic works, the mass catching and over-exploitation of underground waters, wetlands draining, out-of-control spills, bank farming, river bed dredging, changing the natural fluvial system, sweetening of salt marshes or salinizing of rivers are decreasing the diversity of water environments, specially those located downstream and at transition zones.

Before this situation of progressive environmental degradation, public policies have been shifting their posture from *hydraulic* actions, basically devoted to meet the increasing human demand, towards a more *hydrological* approach, based on conservationist principles. Obviously this evolution has not been spontaneous, but it follows the guidelines set by the European Union. The Framework-Directive establishes a series of legal patterns and instruments leading to an environmental recovery. At the same time, other Nature protection and resource managing agreements were executed at an inter-country level, which affect in full water environments. They restrict water extraction, look for ecological quality, control usage, reduce contamination, promote bio-diversity, etc.

In this new context, planning must stand on the basis of a sustainable hydric exploitation, insuring the conservation of every water environment. Before a strategy of mass regulation, it is essential to design efficient exploitation systems based on technologies that maximize performance and minimize expenses, while altering environmental and ecological dynamics the least possible.

In short, we are immersed in a changing context and the most relevant challenge for the 21st century is to establish the legal, managing and scientific-technical mechanisms needed to make possible recovering the natural side of water environments, without renouncing to human society development. It is not an easy and conflict-free issue, but an advanced society can only claim (and safeguard) the sustainability of the ecological, social and patrimonial values of water environments.

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