The role of the Spanish Committee of the International Association of Hydrogeologists in the management and protection of Spain's groundwater resources

Emilio Custodio · M.-Ramón Llamas
Fermín Villarroya

Abstract Spain is a relatively large European country (ca. 500,000 km^2) with extensive semiarid areas in which there exists a large number of good aquifers. In some areas, these aquifers are intensively developed and are the most important sources of fresh water. Nevertheless, groundwater development and protection has rarely been duly considered by the Spanish Water Administration, despite the pressure to remedy this situation by various groups of experts, some of them members of the Water Administration. The Spanish Committee of the International Association of Hydrogeologists (IAH) has been very active during the last decade in promoting activities to spread groundwater science, technology, and management in Spain and outside, mostly in Latin America, and in trying to orient water policy toward issues of groundwater. These activities include mainly the organization of technical and scientific meetings on current topics such as groundwater in the new Water Act, overexploitation, groundwater in water-resources planning, groundwater pollution, natural-recharge estimation and others. The impact of these activities on the recent water policy of Spain seems significant, and the experience gained may be applicable to other countries.

Résumé L'Espagne est un pays européen assez étendu (500,000 km^2 environ), où existent des zones semi-arides possédant de nombreux aquifères intéressants. Dans certaines régions, ces aquifères sont intensivement exploités et constituent les sources essentielles d'eau douce. Cependant, l'exploitation et la protection des eaux souterraines ont rarement été prises en compte de façon correcte par l'Administration Espagnole de l'Eau, malgré les pressions exercées pour remédier à la situation par différents groupes d'experts, dont certains sont membres de l'Administration de l'Eau. Le Comité Espagnol de l'Association Internationale des Hydrogéologues (AIH) a été particulièrement actif au cours de ces dix dernières années pour promouvoir des activités de diffusion des sciences, de la technologie et de la gestion de l'eau en Espagne et à l'étranger, surtout en Amérique latine, et pour tenter d'orienter la politique de l'eau à l'égard des eaux souterraines. Ces activités incluent principalement l'organisation de réunions techniques et scientifiques sur des sujets classiques tels que l'eau souterraine dans la nouvelle Loi sur l'Eau, la surexploitation, l'eau souterraine dans la gestion des ressources en eau, la pollution de l'eau souterraine, l'estimation des écoulements naturels, entre autres. Les retombées de ces activités sur la récente politique de l'eau en Espagne paraissent significatives et l'expérience acquise peut être appliquée à d'autres pays.

Resumen España es un país relativamente grande (unos 500,000 km^2) con áreas extensas en las que existe un elevado número de buenos acuíferos. En algunas zonas estos acuíferos son intensamente aprovechados y constituyen el recurso más importante de agua dulce. Sin embargo, el aprovechamiento y la protección de las aguas subterráneas pocas veces han sido debidamente considerados por la Administración hidráulica española, a pesar de la presión ejercida por distintos grupos y por algunos miembros responsables de la propia Administración hidráulica para corregir esta situación. Durante el último decenio el Comité Español de la Asociación Internacional de Hidrogeólogos (AIH) ha sido muy activo en promover reuniones para difundir la ciencia, la tecnología y la adecuada gestión del agua subterránea en España y en el extranjero, especialmente en Ibero-América. También ha intentado que los temas referentes al agua subterránea tuviesen la oportuna consideración en la política hidrológica general. Estas actividades han consistido principalmente en la organización de reuniones científicas y técnicas sobre temas actuales tales como el agua subterránea en la planificación hidrológica, contaminación del agua subterránea, estimación de la recarga natural y otros. El impacto de estas actividades en la reciente política hidráulica española parece significativo. La experiencia general puede ser aplicable a otros países.

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Emilio Custodio (✉)
Department of Ground Engineering,
Politechnical University of Catalonia,
E-08034 Barcelona, Spain
Fax: +34-3-401-6504

M.-Ramón Llamas, Fermín Villarroya
Department of Geodynamics, Complutense University,
E-28040 Madrid, Spain

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Introduction

Water has long been recognized as a valuable resource and a critical factor in public health and welfare. For several decades, water has also become recognized as being essential for the functioning of most ecosystems. The role of groundwater in the hydrological cycle has been known for more than three centuries. Nevertheless, the potential role of groundwater is often downplayed in the water policy of many countries. Water planners often prefer surface-water solutions even at the expense of conjunctive use of surface water and groundwater, which is either not considered or misapplied. In the early 1970s, the attitude of some hydraulic engineers to draw a sharp distinction between groundwater and surface water, and disregarding the former, was characterized as "hydroschizophrenia" by Nace (1973), a noted hydrologist employed by the U.S. Geological Survey. Llamas (1985) studied this syndrome and concluded that one major cause of hydroschizophrenia in Spain was the failure during the previous century to cope with the increasing water demand of the city of Madrid by means of groundwater using infiltration galleries and water wells. At that time it was decided to import surface water from the nearby mountain ranges with the aid of dams and aqueducts. The centralized nature of the Spanish Administration until the drafting of a new Constitution in 1978, the unhealthy competition between two rival ministries in charge of surface and groundwater, and the promulgation of hydroschizophrenia through most civil engineering schools and research institutions in Spain have helped to spread the malaise across the entire country, thus adversely affecting Spain's national water policy. The private sector did develop groundwater when surface water from public projects was not available, but often without sufficient knowledge or safeguards to sustain this precious resource. There have been some exceptions, such as the successful management schemes of water in Barcelona, but even in those cases the public water administration has often been more of a hindrance than help in the initiation and maintenance of sound groundwater management practices.

The activities of the Spanish Committee of the International Association of Hydrogeologists (IAH) during the past decade have contributed significantly to an improvement in Spain's water policy and management.

Spain is a partially industrialized country with a modest economy in comparison with some other members of the European Union as well as with the United States and Japan. It is the most arid country in Europe, with a climate comparable to the western U.S. The economies of both regions have relied heavily on irrigated agriculture, which is a major consumer of freshwater resources but now is not a major contributor to the gross national product of either Spain or the U.S. This situation is quite different from that in most other countries of the European Union. The purpose of this article is to explain how the activities of the IAH Spanish Committee have contributed to improved knowledge of the role that groundwater should play in the water policy of a semiarid and partially industrialized country such as Spain, and to the implementation of this policy.

Outline of Spain's Hydrogeology and Groundwater Use

Spain is located in the southwestern corner of Europe, separated from Africa by the western Mediterranean Sea. Spain comprises the larger part of the Iberian Peninsula (the rest is Portugal) and includes (a) two main archipelagoes, the Balearic Islands in the Mediterranean Sea and the Canary Islands in the Atlantic Ocean, which face the African continent; (b) two small peninsulas in northern Africa, Ceuta and Melilla; and (c) several small islands. (Locations are shown in *Figure 1*).

Geology

The basement of the Iberian Peninsula is formed by folded and partly metamorphosed Hercynian-age rocks. These rocks crop out in the northern and northeastern parts of Spain and form the basement of the central highlands (Mesetas). Thick Mesozoic-age sediments, predominantly carbonates and marls with evaporites, were deposited around and on the basement rocks. These formations were covered by early Cenozoic-age sediments that contain a large proportion of carbonates along the Mediterranean coast (*Fig. 1*). Mountain ranges, reactivated during the Alpine orogeny, occur at the margins and across the Central highlands, with intensive folding and thrusting of sediments of pre-Miocene age. Large and deep grabens were formed, which are filled with a variety of materials, from arkosic sand to playa-lake evaporitic sediments, mostly unfolded. They constitute a major part of the main river watersheds and contain some extensive aquifers such as those of the Duero and the Madrid basins. General descriptions are in Custodio and Llamas (1991) and Crampon et al. (1996), and more detailed outlines are in Navarro et al. (1989).

In broad terms, the Iberian Peninsula consists of a western and northwestern hard-rock domain; a central domain, dominated by clastic, often fine-grained and clay-rich sediments; and a northern and Mediterranean domain, with extensive thick carbonate formations. Restricted, but thick and well-developed, Quaternary-age deposits along the major river valleys and the coastal plains play important roles as aquifers. Gypsum and anhydrite are widespread in the southeastern part of the Peninsula, where the associated saline waters occur.

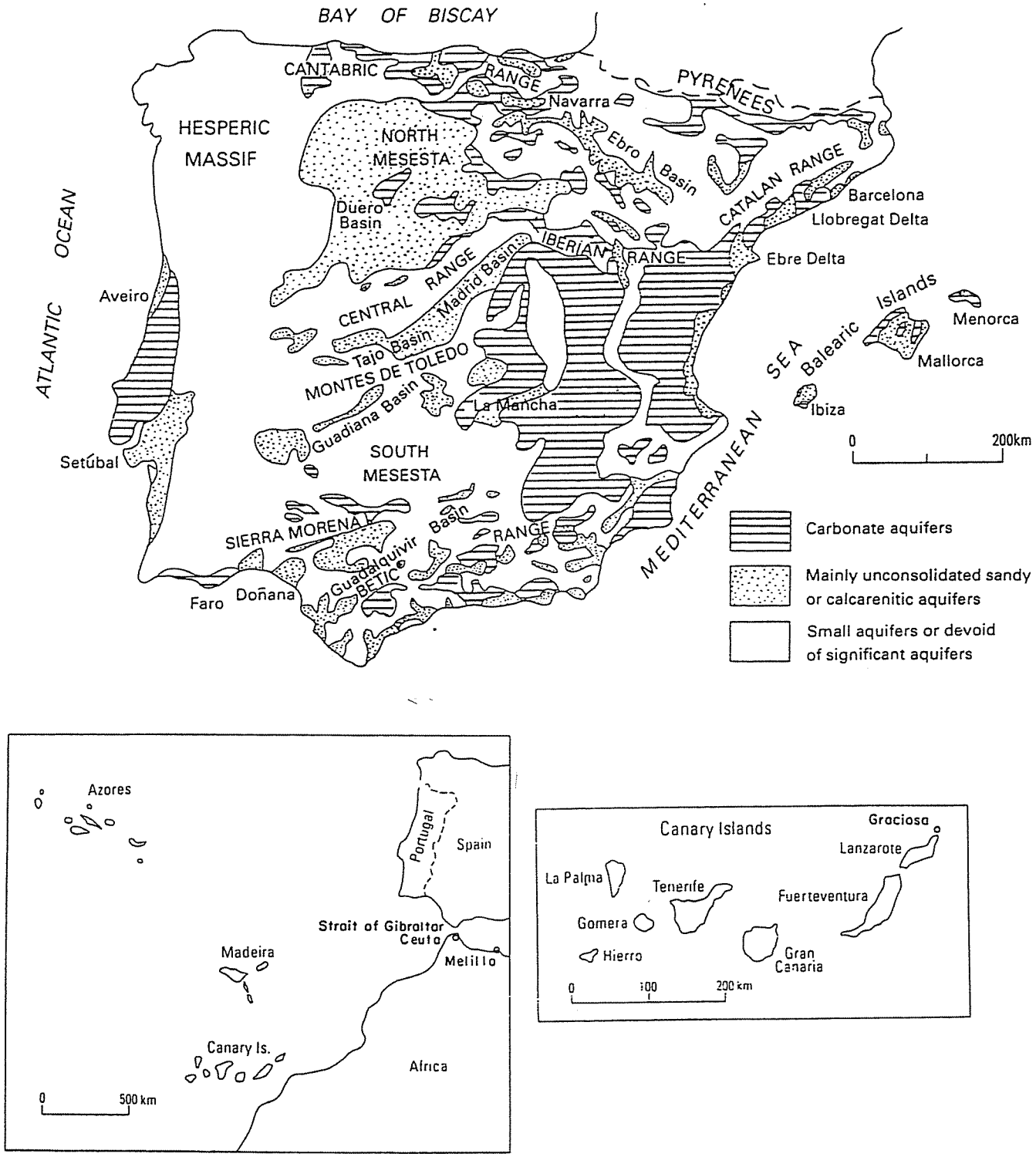

Fig. 1 Hydrogeology of the Iberian Peninsula. (From Custodio and Llamas 1991)

The Balearic Islands are part of the carbonate region of the Mediterranean basin, with a deep sea-occupied trough in between. The Atlantic volcanic archipelago of the Canaries consists of high and large volcanic formations arising from the deep ocean floor, except the easternmost islands, which rest near the African continental shelf. Some islands are very high, up to 3700 m above sea level in Tenerife, from a submarine base more than 3000 m deep. Volcanism started in the Miocene Epoch and comprises several episodes of basic to intermediate eruptions, with intensive landslides, and with intervening dormancy, during which deep gullies

(barrancos) were incised. Volcanism is still active episodically. The oldest parts of the islands have low permeability, but young volcanics are often very pervious. A core of low-permeability material exists that is sometimes exposed but more often buried below recent lava flows that extend down to the coast. The groundwater body may occur at high altitudes, but most of the groundwater flows within the cover of young volcanics (Falkland and Custodio 1992).

Climate

Spain has a diversity of climates due to its position between a temperate European zone and a subtropical area. It includes some of the most rainy areas of Europe, such as Galicia in the northeastern part and Grazalema in the southeastern part, with more than 2 m/a; and the most arid areas, such as Cabo de Gata (Almería) in the southeastern part, with less than 0.2 m/a and some regions of the Canary Islands, with 0.1 m/a). The coastal plains along the Mediterranean, the Ebro (Ebre) central basin and the two main archipelagos (except their high mountains) are semiarid, with a distinct, long dry summer season, during which there is a pronounced soil-moisture deficit and little aquifer recharge.

Groundwater Resources and Aquifers

Of a total surface area of 504,750 km^2, according to official data of "Dirección General de Obras Hidráulicas" (DGOH 1994), 174,745 km^2 are permeable outcrops. Aquifer recharge along these outcrops is approximately 20×10^9 m^3/a, at a rate of 100 mm/a. This amount has been estimated by the Water Administration by assigning recharge rates that range from 16–479 mm/a, to the area of each aquifer system. The Water Administration (SGOP 1990) has identified 442 aquifer systems.

Surface runoff across Spain is officially estimated to be approximately 95×10^9 m^3/a, or approximately five times larger than groundwater recharge. This questionable and poorly supported ratio has been in the past – and still is today – frequently quoted in order to make a case for the construction of large dams at the expense of utilizing, managing, and protecting groundwater.

Groundwater Use

Groundwater is tapped directly at the springs (which often are considered as surface water) or abstracted by means of wells, some of them deeper than 500 m. The number of wells is officially estimated at approximately half a million, but in fact more than one million groundwater uptake points may exist. Following the Water Act of 1985, groundwater became a public commodity. Prior to this act, it was the private property of well owners (Water Act of 1876).

According to DGOH (1994), groundwater uptake increased from 0.5×10^9 m^3/a in 1900 to the current rate of approximately 6.1×10^9 m^3/a. Approximately 1.1×10^9 m^3/a (18%) is used as public drinking water for 31% of the nearly 40 million inhabitants of Spain. Approximately $0.4 \times 10^9 \times m^3/a$ (6%) supplies the industrial sector. The rest, approximately 4.6×10^9 m^3/a, is allocated to irrigation; 700,000 ha of land is irrigated solely by groundwater, and approximately 300,000 ha by groundwater and/or surface water. The total irrigated area of Spain is approximately 3.5×10^6 ha. Surface water is used for the irrigation of 2,500,000 ha at a rate of approximately 20×10^9 m^3/a. In other words, the applied water per hectare in surface-water-irrigated areas is approximately double that of areas irrigated with groundwater.

Most surface-water irrigation projects were constructed in the second half of this century and were financed with public funds. In contrast, groundwater development has been pursued and financed by private farmers and small- or middle-sized towns. This virtually uncontrolled and unplanned development has led to real or apparent problems of (a) overdraft or overexploitation, (b) seawater intrusion, and (c) wetland degradation.

Official data (DGOH 1994) suggest that 51 aquifer units from the total 442 are overexploited, with pumpage exceeding recharge by 0.7×10^9 m^3/a, and 48 units are close to being overexploited. Some complex and partially effective legal action has been taken in 18 aquifer units with a surface area of 13,000 km^2. Abstraction rate is 1.1×10^9 m^3/a, which is assumed to exceed recharge by 0.5×10^9 m^3/a. In some areas in southeastern Spain and the Canary Islands, groundwater drawdown rates as much as several m/a are not rare, but this is not necessarily due to an excess of abstraction over recharge. In some cases a dry period in which recharge is low and/or a long-term transient situation can explain a significant part of such drawdown rates. The term overexploitation has often been used to imply different meanings within different contexts (Custodio 1993, 1996; Dijon and Custodio 1992; Llamas 1992; Llamas et al. 1992; Villarroya 1994a).

Intensive development of coastal aquifers has often produced problems related to seawater intrusion, although many such problems can be attributed to poor management and inadequate well location or construction. These coastal aquifers play, or should play, a key role in peak, emergency, and drought water supplies for towns as well as a complementary source of water for irrigation in coastal areas. According to DGOH (1994), of 82 coastal aquifer units, 15 have been seriously invaded by seawater, 27 other units have large areas with intrusion and 6 units have local problems.

According to the Water Act of 1985, wetlands have to be protected and preserved. The DGOH (1994) study mentions 1533 groundwater-related wetlands of various sizes, with a total current surface area of 800 km^2, approximately 65% of the original 1250 km^2. Some of them, including several that have international relevance, are being threatened or degraded by

groundwater abstraction, but in other cases the assumed ecological impact of groundwater abstraction has been used to justify the construction of large dams for other purposes (Llamas 1994).

Official data on groundwater contamination are scarce and sketchy, even for natural sources of salinity, which play a significant role in some areas. Aquifer pollution by human activities may be serious in some areas (Custodio 1992), although fortunately there are large areas of rural, forest and natural parks in which the risk of pollution is small. Agriculture is a main contributor through massive use of fertilizers and other agrochemicals for intensive crop production, mainly along the Mediterranean coast and on the islands. According to DGOH (1994), the mean rate of nitrogen use in agriculture has increased from 12 kg/ha/a in 1955 to nearly 60 kg/ha/a in 1988. In parts of some aquifers there are areas in which NO_3^- in groundwater exceeds the 50-mg/L limit for drinking water, in places reaching 200 or even 500 mg/L. Current use of pesticides ranges from 2–12 kg/ha/a, but studies of their impact on groundwater are scarce. In some areas, intensive raising of livestock causes serious nitrate problems and reducing conditions in groundwater that increase iron, manganese, and other heavy-metal concentrations.

A few documented cases exist of groundwater contamination by hydrocarbons, organic chlorinated solvents, and heavy metals; however, data are scarce. Such cases are not mentioned in the White Book on Groundwater by the DGOH (1994). New cases are appearing more and more often, showing that it seems to be a widespread problem. Such industrial contamination may jeopardize the sustainable use of aquifers as an inexpensive and reliable source of water in case of drought, emergency, and peak demands in and around urban areas.

Main Problems with Spanish Groundwater Policy

Llamas (1997) categorizes the causes of water problems in the Iberian peninsula as either ethical, aesthetic, or technological. The salient points of his paper in relation to groundwater are summarized below.

The main reason for the relatively scarce use of groundwater in Spain, and for its poor management with consequent overexploitation, seawater intrusion, wetland degradation, and groundwater pollution, is the method by which taxpayers' money is allocated to water projects. Most dams and canals built for irrigation projects, or for water supply to large towns, during this century have been designed and paid by the Ministry of Public Works. Only dams built for hydropower have been financed by the private or semipublic sectors. The method was – and still is in a certain way – similar to the American "pork barrel" method, where members of Congress append items to bills so as to benefit narrow interests of their local constituencies (mainly for large hydraulic works) at the expense of the public at large. In Spain, the lobbies of large constructors and of farmers have been – and still are – very successful in draining public funds for large hydraulic works for urban water supply or irrigation. On the other hand, groundwater development has been financed primarily by private entities, mainly farmers of modest means, local water suppliers and factories. It is not easy to alter this situation because of: (a) the mental inertia of many engineers involved in water management who think in terms of "hydraulics" rather than "water resources;" (b) the lobbying power of large construction companies; (c) the persistence of the "pork barrel" mentality among politicians; and (d) a corrupt atmosphere that may surround public works.

Another obstacle to the rational use of groundwater is the poor participation of groundwater users in the management of aquifers. Prior to the 1985 Water Act, most officials of Water Authorities paid little attention to groundwater resources under the pretext of having no legal or mandatory control over such waters. This situation is in contrast to traditional social participation of surface-water users in its management. A prime example is the well-known "Tribunal de las Aguas" (Water Jury) of Valencia that has been in operation for seven centuries. The 1985 Water Act attempted to create similar participation among groundwater users, but thus far, corresponding efforts by Water Authorities have been largely unsuccessful, with a few exceptions.

Most systematic hydrogeological surveys have been conducted by the Geological Survey of Spain (ITGE). The Ministery of Publics Works had only a small team of hydrogeologists, some of whom were of excellent professional level but held little authority. Twelve years after the 1985 Water Act, the number of hydrogeologists among officials of the Water Authorities remains pitifully small. This lack of expertise with authority within the Spanish Water Administration is a major reason for the underexploitation, the overexplotation, and the general mismanagement of groundwater resources in Spain. It is also responsible for the "illusory accuracy" of groundwater statistical data in Spain (Llamas 1997). This situation, coupled with the old adage "out of sight, out of mind," explains why the Spanish public has such uninformed and biased perception of groundwater that does not identify it as an important resource that requires careful management. This is also why legal and administrative control of groundwater quality is so weak, despite improved legislation concerning water supply. Groundwater pollution is seldom mentioned, and when it is referred to the objective usually is to justify large surface-water or desalination projects to supply potable water to urban areas formerly supplied with the unpolluted groundwater.

As it happens, with a few exceptions groundwater has never been properly investigated or controlled by Spain's Water Authorities. Instead, hydraulic engineers working for the Water Authorities are often responsible for many "hydromyths" regarding groundwater that have been circulating through Spain in recent years

(Custodio 1996; Custodio and Llamas 1997). Among these hydromyths, perhaps the most pervasive is that "the fate of every water well is to become dry or brackish." The logical conclusion of this wrong philosophy has been the continuation of construction of large dams and canals.

Development and Activities of IAH in Spain

Spanish membership and participation in IAH activities dates back to the establishment of the organization, in 1956 in Mexico City. The second author of this paper was elected a member of the IAH Council in 1980; president in 1984; and served in the Council as past president until 1992. In the same year, the first author of this paper was elected member of the Council and reelected in 1996. The presence of two Spanish members in the IAH Council has been a major impetus for the development of IAH in Spain.

The first formal plenary meeting to elect members of the IAH Spanish Committee took place in Barcelona during the 1981 Spanish Conference on Groundwater Contamination, organized by the "Curso Internacional de Hidrología Subterránea" (International Course on Groundwater Hydrology). At that time, the first author was elected president and charged with the formal organization of a Spanish IAH chapter (AIH-GE). In the early 1980s, the chapter had fewer than 50 members. In 1986, the third author was elected Chairman of the IAH Spanish Committee and reelected again in 1990, to be followed in 1993 by the first author. As shown in *Figure 2*, the number of Spanish IAH members has increased continuously from fewer than 100 members in 1986 to over 350 members in 1996. Most Spanish IAH members are geologists, but there are also numerous civil and mining engineers with a smaller number of industrial and agricultural engineers, lawyers, chemists, and others. The IAH Spanish Committee has been legally incorporated as a non-profit association.

The IAH activities in Spain have been focused in large measure on how to adapt European Union directives relative to groundwater to special circumstances of Spain; how to improve the understanding of groundwater by managers and policy makers; to update groundwater regulations; and to modify institutional behaviour, so as to deal effectively with groundwater development, protection, and management in the country. The activities have been aimed preferentially at water managers, policy makers, and at the institutions and companies for which they work. The issues of science and technology have also been addressed but with lesser emphasis. Professional meetings and corresponding publications organized by the Spanish National Committee include:

1. Study of groundwater contamination in Spain: Barcelona (Custodio et al. 1981); Alcalá de Henares (Rebollo 1994).
2. Groundwater in the 1985 Water Act: Zaragoza (Martínez Gil et al. 1988).
3. Aquifer overexploitation. In Spain: Almería (Pulido Bosch et al. 1989); IAH Congress: Puerto de la Cruz, Tenerife (Candela et al. 1991).
4. Groundwater in water planning after 10 years of the Water Act: Murcia (AIH-GE 1995).
5. Role of groundwater in water planning. In northeast Spain: Lleida (AIH-GE 1996); in the Canaries: Las Palmas de Gran Canaria (Cabrera et al. 1997).
6. Recharge estimation in groundwater planning: Las Palmas de Gran Canaria (Custodio et al. 1997).

More specialized meetings that the Spanish IAH helped organize include:

1. Well construction and maintenance: Madrid (Villarroya 1994b).
2. Design of wellhead protection areas: Barcelona, 1995 (unpublished).

These activities were in addition to half-day meetings devoted to current issues on hydrogeology and groundwater management, mostly in Madrid, in which a panel of experts would present key ideas and the floor would be open for a lively discussion. These meetings have resulted in summary notes or short papers. The two most widely attended short meetings were devoted to groundwater in the Proposal of the National Water Plan and in the Advancement of the National Irrigation Plan. Several national working groups have been recently established to address pesticides in groundwater, hard-rock hydrogeology of the Iberian peninsula (with the participation of some Portuguese colleagues), and research needs in Spain's hydrogeology. The group on pesticides is multidisciplinary and open to non-members of the IAH.

Approximately 50% of the Spanish IAH members belong to a sister association, called the "Asociación Española de Hidrología Subterránea" (AEHS; Spanish Association of Groundwater Hydrology), founded in 1975. This association organizes a National Symposium on Hydrogeology every 3 or 4 years that deals with a broad range of issues. It also publishes the journal "Hidrogeología."

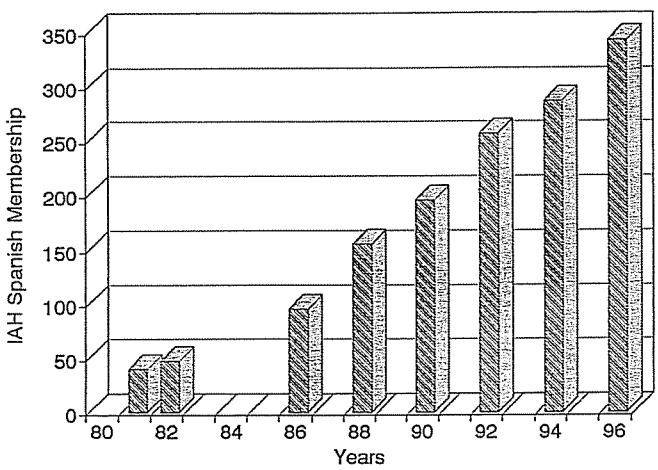

Fig. 2 Spanish membership of the AIH

Some Significant Contributions of IAH to Groundwater Management and Protection in Spain

In Spain, like elsewhere, the IAH contributes to the development and dissemination of information concerning advances in groundwater science and technology. Of particular impact were conferences and publications in which there had been broad participation of persons with differing viewpoints, or experts representing different socioeconomic sectors and interests. The format varied and included:

1. Invited speakers to review the background and current situation concerning a given topic. When dealing with groundwater management, two persons from different sectors (water administration and water users; public managers and private owners; researchers and practitionists) would sometimes be asked to present opposing points of view. An open discussion would follow, often inspired by written questions from the audience.
2. Panels of three to five persons to present briefly key aspects of a topic, followed by a panel discussion. Panel members would be selected to represent differing interests or trends. Each member would be asked to prepare a short paper with an opportunity to redraft it, based on the results of the discussion.
3. Contributed papers with an opportunity to redraft them based on the results of the discussion.

At times, experts decline invitations to participate in AIH-sponsored conferences due to mistrust, fear to express their thoughts, or simply lack of interest.

Of special relevance have been two conferences on the Water Act of 1985 (Martínez Gil et al. 1988; AIH-GE 1995), in which practical difficulties facing the implementation of groundwater management were pointed out and remedies suggested. Inconsistencies and misconceptions relating to aquifer overexploitation, risk of salinization, groundwater planning, and aquifer protection were debated, and it was shown that aquifer pollution had been insufficiently and unrealistically considered. In response to these discussions, the government is presently considering amendments to the Act that could help to resolve these problems.

In 1989, one national Conference on aquifer overexploitation (Pulido Bosch et al. 1989) was focused on one of the most controversial, poorly defined, and complex aspects of the Spanish Water Act. As the issue is of wide interest, it was also discussed at an international conference in Puerto de la Cruz, Tenerife, Canary Islands (Candela et al. 1991; Simmers et al. 1993) and at a follow-up meeting of experts in Las Palmas de Gran Canaria, Canary Islands (Dijon and Custodio 1992), convened jointly by the United Nations and the Spanish Government but organized by Spanish members of the IAH.

Aquifer overexploitation and the related aspects cannot be easily defined, because many different circumstances exist. Besides classical hydrogeological and hydrochemical considerations, other aspects also play an important role, such as economics, social behaviour, and conditions of regional development. Each case merits a special study under local circumstances and in relation with other water resources to decide which regulations are better suited to deal with regional or local aquifer-intensive development. Use of groundwater reserves is inherent to dynamically transient situations. A sustained trend at groundwater-level drawdown during some time period does not mean necessarily that abstraction is greater than recharge. Even recharge is a variable input affected by water development, human activities and changes in the land, and can be artificially modified to some extent if water is available and the cost is bearable. Water-quality aspects of aquifer development is an equally important issue, rarely considered when dealing with aquifer overexploitation. Often some extent of aquifer overexploitation is a blessing for developing areas at the initial stages, and this situation tends to correct itself if market economics are applied to water, with regulations to protect the social and environmental role of groundwater.

Overexploitation is a key (real or apparent) issue in Spain and thus explicitly considered in most conferences in some way. This is something that has to be considered in the Spanish Water Plan and the Basin Water Plans. These plans complement the Water Act but their preparation and approval have met with major difficulties. Their preparation started in 1980, but, to date (1997), no plan has been finally approved. They should ideally be updated from time to time due to changing conditions, but this is even more difficult given that the Water Plans have until recently attempted to regulate everything instead of guiding management decisions. In these Water Plans, groundwater is barely considered; few economic resources are devoted to its preservation and management; its role and nature are sometimes misinterpreted; and large, expensive surface-water investments are preferred to usually less expensive groundwater development. The IAH Spanish Committee has made an effort to intervene by being the first group to organize a panel and discussion of the first Proposal of the National Plan (MOPU 1993) and officially informing the government about conclusions and recommendations (Villarroya 1993). Several members of the IAH published papers and comments on the draft National Water Plan. Those and other critiques of the Water Plan were so severe as to prevent the government from forwarding the plan to the nation's parliament for approval. After the general elections of March 1996, the new government formulated a new policy. In preparation is a "white book" on water resources to be openly discussed, with the aim of reaching broad consensus on a socially acceptable report, which would become the basis for a revised National Water Plan. This water plan would probably be included in a short document to guide government and Basin Water Authorities in their policies on water research, development, protection, and management. The plan would be flexible for easy update and would avoid the rigid

regulations of previous drafts. Since most groundwater is used for irrigation, when the government issued a draft of the National Irrigation Plan, a panel was convened to discuss relevant groundwater issues.

Because Spain presents a variety of water problems, the IAH has adopted a regional approach to deal with the role of groundwater in the water plans. To date, it has considered the northeastern area (Ebre basin, Xúquer basin and Internal basins of Catalonia; AIH-GE 1996) and the Canary Islands (Cabrera et al. 1997); other areas are slated for similar examination in the future. New information will be incorporated in the Water Plan through updates. Among key issues identified at Spanish IAH conferences are the lack of basic information; the need for research and development; ways to foster participation of groundwater users in aquifer management; the opportunity to foster a market in water, under well-defined economic rules, even though water continues as public domain; and the need to introduce real economics in the water market, instead of relying on public funds in the name of public or general interest. The general-interest argument renders management of water expensive and forces politicians to pursue narrow interests instead of the common good; creates an atmosphere of conflict among regions; and obscures the real economic, social, and environmental value of water.

One of the key difficulties associated with the assessment of groundwater resources in semiarid regions is the estimation of natural recharge. This has been the focus of previous IAH efforts (Lerner et al. 1990) as well as of a book soon to be published. Improved estimates of recharge, and of groundwater residence time in aquifers, are required to produce realistic aquifer utilization, protection, and management plans. To help water planning in Spain, the IAH Spanish Committee organized a seminar on this topic (Custodio et al. 1997). The seminar revealed that, despite claims of serious overexploitation and salinization of some aquifers made in the proposals of the water plans, only rough and unverified estimates of recharge are available in most cases. Methods used to obtain these estimates vary and cannot be compared. The simple and reliable method of salt balance was either not employed to obtain mean values of recharge in arid regions, or its results have not been taken into account. No attempt was made to quantify uncertainties in the estimations of recharge or residence time. Recharge in piedmont areas and barrancos (gullies), very significant in the Mediterranean region and the archipelagoes, was seldom taken into account. The seminar was instrumental in pointing out these methodological deficiencies, identifying research needs, and listing approaches that may work.

Groundwater contamination from natural sources caused by aquifer hydrodynamics due to its development, and aquifer contamination due to human impact are not realistically considered in the Water Act and are downplayed in the water plans. Information is poor and studies dealing with groundwater contamination are few. The traditional focus has been on estimating water quantity, not on assessing its quality. This has been a main concern for the IAH Spanish Committee, and the first conference was devoted to this topic (Custodio et al. 1981), to be repeated later (Rebollo 1994). Publications and papers contained in the proceedings of the AEHS meetings ("Hidrología y Recursos Hidráulicos") are still the main source of information on subjects such as salinity, nitrate buildup, pesticides, iron and manganese occurrence in aquifers with a heavy load of organic matter, oil and organic chlorinated solvents, boron, increased fluorine, etc. The role of the IAH is to inform, but also to demonstrate how the contamination can be prevented, the aquifers can be protected and restored, sound management and well construction practices are possible, and hydrogeologists can cope with these situations given adequate public and private support.

Conclusions

Spain was and is one of many countries whose water policies fail to properly consider groundwater as a resource. Instead, taxpayers' money is often wasted on unnecessary, grandiose but inefficient water works in which management of water, and especially groundwater, is of secondary importance. Aquifers are not well protected and become salinized or contaminated through human activities that often bear no relationship to groundwater development. Valuable wetlands have been destroyed by incorrect aquifer development and management.

Some IAH Spanish members and the IAH National Committee have been very active in fostering greater awareness of the relevance of groundwater resources to the country among water managers, the public water administration, and groundwater users. Such awareness has been considered a priority and has taken precedence over the solution of science and technology issues. A similar mode of action may be useful for some other countries, especially in Latin America, where legal and administrative structures may resemble those of Spain.

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